SUPPORTING COGNITIVE ENGAGEMENT IN A LEARNING-BY-DOING LEARNING ENVIRONMENT: CASE STUDIES OF PARTICIPANT ENGAGEMENT AND SOCIAL CONFIGURATIONS IN KITCHEN SCIENCE INVESTIGATORS

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SUPPORTING COGNITIVE ENGAGEMENT IN A LEARNING-BY-DOING LEARNING ENVIRONMENT: CASE STUDIES OF PARTICIPANT ENGAGEMENT AND SOCIAL CONFIGURATIONS IN KITCHEN SCIENCE INVESTIGATORS

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To My Mom, Darlene Gardner Vaughn

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SUMMARY

Learning-by-doing learning environments support a wealth of physical engagement in activities. However, there is also a lot of variability in what participants learn in each enactment of these types of environments. Therefore, it is not always clear how participants are learning in these environments. In order to design technologies to support learning in these environments, we must have a greater understanding of how participants engage in learning activities, their goals for their engagement, and the types of help they need to cognitively engage in learning activities.

To gain a greater understanding of participant engagement and factors and circumstances that promote and inhibit engagement, this dissertation explores and answers several questions: What are the types of interactions and experiences that promote and /or inhibit learning and engagement in learning-by-doing learning environments? What are the types of configurations that afford or inhibit these interactions and experiences in learning-by-doing learning environments?

I explore answers to these questions through the context of two enactments of Kitchen Science Investigators (KSI), a learning-by-doing learning environment where middle-school aged children learn science through cooking from customizing recipes to their own taste and texture preferences. In small groups, they investigate effects of ingredients through the design of cooking and science experiments, through which they experience and learn about chemical, biological, and physical science phenomena and concepts (Clegg, Gardner, Williams, & Kolodner, 2006).

The research reported in this dissertation sheds light on the different ways participant engagement promotes and/or inhibits cognitive engagement in by learning-by-

doing learning environments through two case studies. It also provides detailed descriptions of the circumstances (social, material, and physical configurations) that promote and/or inhibit participant engagement in these learning environments through cross-case analyses of these cases. Finally, it offers suggestions about structuring activities, selecting materials and resources, and designing facilitation and software-realized scaffolding in the design of these types of learning environments. These design implications focus on affording participant engagement in science content and practices learning. Overall, the case studies, cross-case analyses, and empirically-based design implications begin to bridge the gap between theory and practice in the design and implementation of these learning environments. This is demonstrated by providing detailed and explanatory examples and factors that affect how participants take up the affordances of the learning opportunities designed into these learning environments.

CHAPTER 1

INTRODUCTION AND MOTIVATION

In science, I just sit there and look at a book. And like in science, the teachers tell you to open a book and read by yourself, some people really don't read the book, they'll just be sitting there pretending like they're reading or something. A lot of times when the teacher asks you a question, you don't know. And they can tell you're not doing nothing.

- Malaysia's Interview after the conclusion of Enactment #2 of KSI

Craig and Brett knead the pizza dough while William and KJ watch. The girls from the group next to them begin tasting the dough that is all over their hands. One of the boys from the group exclaims, "You're tasting it?!" KJ announces with his hands covered in dough, "I'm licking my finger." While the others pinch off pieces of the dough, KJ says, "I'm going to describe what it tastes like." Then KJ and William taste the dough but Brett says, "I'm not tasting it." Then William and KJ have a conversation while thinking about what the dough tastes like while Brett and Craig continue kneading the dough:

William: "Chewy, but" [He stops talking and looks at KJ with a whimsical look]
KJ: "Chewy, but like," [pause] "chewy!" [All this is said while he is looking off into the air with a thought-engrossed look on his face]
William: "Chewy, but a little bit. A little bit. It has a taste of salt." [He says this while pointing at KJ in a manner that suggests this is his well thought out conclusion]

Then KJ looks towards Craig who is still kneading the dough and says, "We've been working it out for a while we need to let it rest." KJ picks at the dough on his fingers.

William, with the timer in his hands, says, "Let's let ours rest. Guys lets' let it rest. She said let's let it rest." Craig leans over and tells him 8 minutes then turns away. William sets the timer then sets it down on the table and says, "let it rest," as he turns toward Craig and they walk to the kitchen to wash their hands.

Excerpt from KSI Enactment #1 – Day 1 – Pizza

1.1 Motivating Problem

When science content is too abstract, has little relevance to everyday life, and does not engage students in scientific practices, it leads to brittle learning that rarely leaves the classroom (Chinn & Malholtra, 2002; Science For All Americans, 1990). As conveyed in the first excerpt, Malaysia's experience suggests that this is still a common experience for students in science classrooms today, even though for over two decades, there has been a call to engage kids in science more deeply and in more meaningful and authentic ways (Chinn & Malholtra, 2002; Science For All Americans, 1990). In contrast, the second excerpt highlights what it looks like when participants are deeply engaged in investigating scientific phenomena and making descriptive observations in the context of cooking.

The two excerpts above illustrate the diversity of science learning opportunities available for students inside and outside of the classroom. On one end of the spectrum, there are traditional approaches to science education that have students read about science from a textbook and the result, as Malaysia suggested, is often disengaged students who do not get much out of the experience. On the other end of the spectrum are "learning-by-doing" approaches that engage participants in science through hands-on and inquiry activities where students learn scientific principles and seek to do more and learn more than is required.

The two excerpts come from participants in Kitchen Science Investigators (KSI), a learning-by-doing approach to supporting science learning through cooking that was created in the Learning by Design Lab under the direction of Janet Kolodner, Tammy Clegg and myself. In KSI, participants customize recipes to their own preferences, and in the process they investigate the effects of ingredients through the design of cooking experiments. They learn about chemical, biological, and physical science concepts through seeing and experiencing chemical and biological reactions and changes in the foods they create (Clegg, Gardner, Williams, & Kolodner, 2006). For example, the boys from the second excerpt were preparing pizza dough to learn about the role that yeast plays in making pizza dough rise and saw that while the dough was resting it increased in size because of the carbon dioxide the yeast produces when it metabolizes the sugars in the dough. The second excerpt highlights an instance where these boys were making concrete observations of the kind Chinn & Malhotra (2001) suggest scientists make when they are describing scientific phenomena. In KSI, we selected cooking activities where participants needed to use scientific practices or knowledge to achieve their own goals to serve as vehicles for covert engagement in scientific content learning and practice.

A *learning-by-doing learning environment* is a place where participants explore and learn disciplinary ideas, concepts, and practices while engaged in some set of constructive activities authentic to the discipline and fun or interesting to the learner. In science learning-by-doing learning environments, participants engage in science practices while achieving design challenges or solving problems that require science content or scientific reasoning for their completion. Learning is driven by participants' interests and goals as they attempt to address the challenge or answer the question.

As in KSI, other learning-by-doing learning environments engage learners in learning in the context of design or problem solving activities interesting to participants. For example, in the Computer Clubhouse, kids explore their own ideas through designing websites, creating their own music, and carrying out other projects of their choosing

(Resnick, 2002). In TERC's Astrobiology curriculum for after-school programs, middle school children learn about biology and astronomy through the context of extraterrestrial life, and study how life arises and persists on other planets (TERC, http://www.terc.edu/work/422.html). In Hovercrafts, middle school children explore physics concepts, including gravity and force, through designing hovercraft skirts and optimizing fan positioning to achieve design challenge courses (Vattam & Kolodner, 2008). Each of these programs uses the design of artifacts and interactions with peers and facilitators to pique the scientific curiosity of participants, thus providing a context for application and extension of what they know in order to learn new disciplinary content, skills, and practices.

In general, learning-by-doing science learning environments provide affordances for participants to engage deeply with science content both physically and cognitively. For example, KSI has affordances to physically engage participants by providing opportunities for them to interact with artifacts, (e.g., touching, tasting, smelling, and experiencing scientific phenomena firsthand). Additionally, KSI offers affordances for engaging participants cognitively through providing opportunities to make connections between observed phenomena and scientific explanations. This requires reflection and understanding of scientific concepts, ideas, and processes.

In addition to the physical and cognitive affordances for learning, many learning-by-doing learning environments have affordances for engaging participants socially. In KSI, participants interact with one another in small groups while preparing recipes and conducting experiments. In the process, they discuss plans for activity coordination and aspects of the activity they find interesting.

Current research on learning-by-doing learning environments has focused on how to design activities, artifacts, and programs that leverage authentic and exciting activities to pique the scientific curiosity of participants. Such environments provide a context in which participants apply and extend what they know to learn new content knowledge, skills, and practices. Thus, great effort must be put forth to ensure that participants are having the right kinds of interactions with artifacts that will result in observation of scientific phenomena and promote reflection.

A major challenge has been in understanding how to take advantage of participants' interests in these exciting activities to motivate them to take on scientific goals. Learning-by-doing program designers, facilitators, and researchers have found that children can get so caught up in the activities themselves (e.g., building model rockets, beating eggs for brownies, attaching larger wheels for their mini-race car) that they do not want to take time to look up from their activities to reflect on what they are doing and why (e.g., What makes the rocket soar into the air? Why do I need to beat the egg? What will bigger wheels allow my car to do?). As a consequence, there is a lot of variability in what participants learn in these learning environments. While the expectation in these environments is that participants will learn different things depending on what they are most interested in, not all participants learn as much or as deeply as they could.

The differential quality of what is learned by participants is at least partially due to participants' tendencies to engage physically but not cognitively. This is especially the case with programs lacking formal evaluation of participants' learning, because often they do not hold children accountable for their engagement. In addition, learning variability can be partially explained by differences in facilitation approaches taken to address the diversity of participants' interests. The logistics involved in operating these programs (e.g., network connectivity, computer software glitches, availability of resources, and access to facilities) also contribute to variability, as they affect enactment of the learning environments and subsequently the types of experiences participants have in these learning environments.

Differences between enactments make it difficult to understand exactly what factors are affecting participants' learning. And, not understanding how to control learning variability has negative consequences on the adoption of learning by-doing-approaches in schools and other institutions of learning that must have predictable measures of learning to fund the programs. This seems unfortunate, as learning-by-doing learning environments have such great potential for providing a real-world context for disciplinary content, skills, and practices and for inspiring and equipping the next generation of scientist and scientifically literate citizens. For wider adoption, it is important to understand how to reduce or control the variability in quality of participants' learning.

Recent research suggests that we can begin to understand such variability by examining the ways participants engage in activities and discourse and what influences their willingness to engage and the ways they engage. For example, Engle & Conant (2002) suggests that only if participants have authority to and accountability for problematizing activities will they take up the affordances for learning that activities are designed to support. In addition, Scardamalia and Berieter's research suggests that participants taking on collective cognitive responsibility for their learning is essential to learning in a collaborative environment (Scardamalia, 2002; Scardamalia & Bereiter, 1991). This requires participants to have a disposition or a willingness and knowledge of the actions they could be carrying out to promote their own learning and that of others (Bereiter, 1995). Greeno (2006) suggests that the ways participants position themselves and are positioned by others as knowledgeable and capable affects the degree to which they engage and learn.

This collection of research shows how learning can be thwarted by unintended characteristics of an environment and unanticipated capabilities or attitudes of participants. This suggests that if we want to understand variations in what participants learn in learning-by-doing environments, we need to broaden our focus beyond the affordances designed into the learning environments and learning materials and also identify the range of factors that influence the conditions under which participants recognize and take up those learning affordances.

Understanding the factors that influence engagement and subsequent learning in learning-by-doing learning environments is important for at least three reasons. First, it may provide suggestions about how to reduce the variability of learning in learning-by-doing learning environments. Second, a better understanding of how participants engage in these learning environments and the potential positive and negative consequences of different ways of engaging may suggest guidelines for better designing and facilitating activities in such learning environments and for measuring and assessing learning. Finally, understanding how participants engage in these learning environments can help us consider the roles that technology might play in supporting learning and cognitive engagement in these learning environments.

1.2 Purpose

Through the work presented in this dissertation, I seek to extend understanding of how moment-by-moment participant engagement affects learning in learning-by-doing learning environments. My aim in the research reported in this thesis is to understand how different ways of engaging promote or inhibit opportunities for learning that are intended in learning-by-doing learning environments. I aim to begin bridging the gap between theory and practice in the design and implementation of these learning environments. This requires me to understand participants' interactions well enough to offer suggestions about structuring activities, facilitation, and other scaffolding in the design of learning environments that not only potentially <u>afford engagement</u> in the learning of science content and practices, but that <u>actually result in such engagement</u> and subsequent learning.

My strategy to achieve this is twofold: (1) I provide an in-depth look at the ways participants' interactions and experiences in learning-by-doing activities facilitated or hindered their engagement and learning in several enactments of KSI; and (2) I identify relationships between participant engagement, and the physical, social, and material configurations of learning environments that afford and constrain the engagement and learning in those environments.

This dissertation addresses the following research questions:

(RQ 1) What are the types of interactions and experiences that promote and /or inhibit learning and engagement in learning-by-doing learning environments?

(RQ 2) What are the types of configurations that afford or inhibit these interactions and experiences in learning-by-doing learning environments?

1.3 Context of Research

I use several implementations of Kitchen Science Investigators (KSI) as a research context for addressing these questions. KSI is an afterschool program designed to promote learning of science and scientific reasoning in the context of cooking (Clegg, Gardner, Williams, & Kolodner, 2006; Clegg & Kolodner, 2007). The program is designed for middle school-aged children (11-14 years old). They learn science through hands-on cooking and science activities that allow them to experience science and recognize the roles science and scientific reasoning play in their everyday lives. Since the spring of 2004, KSI has been offered three times as a 10 – 20 week after-school program and four times as an intensive weeklong summer camp. The program was designed and facilitated by Tamara Clegg and myself and has been the focus of both of our PhD theses.

Analysis of the program suggests that it has been successful at piquing middle-school aged learners' interests in science and helping them to recognize and value the roles that science plays in their everyday lives (Clegg, 2010). One way that we have done this is by helping learners to recognize the roles that various ingredients play in making food rise and thicken (Clegg, Gardner, Williams, & Kolodner, 2006). This allows them to experience how using science can help them accomplish everyday goals. We've found that participants in KSI cook more at home as a result of participating in KSI and eagerly share what they have learned about how ingredients work, science content, and scientific reasoning with their families and friends. We've also found that they use scientific practices they've learned from their experiences in KSI in their science classrooms.

KSI has been iteratively refined as part of a design-based research project aimed at studying situated learning and identity development. And KSI, like any other afterschool program, has had to be varied in different implementations as a function of the goals and interests of the participants and the available resources and facilities. The program has thus evolved as a result of both what was learned in earlier enactments and the particular interests of participants and facilities available.

The design of KSI leverages knowledge gained from previous studies of learning, including Learning By Design (Kolodner et al., 2003), Knowledge Integration (Slotta, 2004), Knowledge Building (Scardamalia & Bereiter, 1991), and Islands of Expertise (Crowley & Jacobs, 2002). Each of the iterations of the program has maintained the integrity of the ideals of these predecessor approaches.

KSI provides a real-world context in which to explore interactions and experiences in learning-by-doing learning environments, and the ways naturally-occurring factors facilitate or inhibit learning. Our primary goal in facilitating the program was to provide quality and enjoyable learning experiences for the participants. Thus, we minimized the intrusion of our research agenda as much as possible, so that the program would not appear to be any different from other afterschool programs in which learners may have participated.

In designing KSI, we attempted to sequence the activities so that a culture of inquiry emerged among participants. We wanted participants to feel comfortable being curious, asking questions, exploring topics that are interesting to them, and expressing their ideas, even those that might not be fully developed. We made resources and tools available to help participants understand science content and to help them develop and practice scientific reasoning (Gardner, Clegg, Williams, & Kolodner, 2006). Our goal has been to build on and adapt what we know about classroom learning to fit the needs and goals of supporting learning in afterschool learning environments.

The primary context for learning science and scientific reasoning and the practices of scientists in KSI is recipe preparation, and learners engaged in recipe preparation and associated activities during two-thirds of their time in KSI. We designed KSI so that recipe preparation would play a variety of roles in helping participants learn science and scientific practice:

(1) Participants prepare recipes of their own choosing, or fun ones like brownies, pizza, and cake to stimulate their interest and make them want to know more about how these foods were prepared.

(2) Preparing the recipes themselves affords learners noticing changes as they add ingredients. This in turn promotes curiosity about why different ingredients had different effects. Seeing and feeling the differences while mixing, kneading, and otherwise handling the ingredients and utensils are both important for recognition of changes.

(3) Participants conduct science experiments and activities that highlight the scientific phenomena they are observing to help them make connections between the recipes they prepare and the science behind the changes and results they observe.

(4) Designing and conducting the experiments themselves gives participants opportunities to engage in authentic scientific practices and to value those practices, because the analysis of experiment results helps them to solve problems important to them.

(5) Participants work in small groups so that they have opportunities to work together and have conversations about what they are noticing and doing, promoting reflection-in-action and reflection-on-action, while simultaneously allowing participants to learn from one another.

(6) Opportunities are built in for participants to share their findings and results across groups during big group conversations. This is designed to promote comparison making, reflection, and conclusion drawing.

This whole set of activities is designed to promote participant ownership and agency as participants are integrally involved in shaping the direction of the activity. For example, they are involved in the planning of the experiments, responsible for carrying out their variation of the experiment, and responsible for reporting back to the group to share their artifacts, observations, and their results.

We found that each of the design decisions listed above was important for promoting learning. However, some worked differently than we imagined, so we had to refine the way some were enacted, and naturally-occurring factors affected the quality of participants' engagement and learning. Since we ran several enactments of KSI, we had the opportunity to look for potential causes for why there were learning differences between the two learning enactments. In particular, one key finding emerged with respect to the role the physical layout of the environment played in supporting participants' engagement and learning in both enactments.

1.4 Research Questions & Dissertation Findings

In this dissertation, I use two enactments of KSI as contrasting contexts for addressing my two research questions.

(RQ 1) What are the types of interactions and experiences that promote and/or inhibit learning and engagement in learning-by-doing learning environments?

To answer this question, I constructed two case studies that highlight the types of interactions and experiences that promoted or inhibited learning in KSI. My qualitative analysis of these enactments allowed me to organize the types of interactions and experiences in these environments into three dimensions of engagement: Sensory, Social, and Cognitive. Sensory Engagement means having first-hand and second-hand experiences with phenomena and material (i.e., personal tactile, visual, and auditory experiences and observation of other participants' sensory engagement). These experiences sparked participants' interests and provided opportunities for participants to intentionally monitor artifacts and activities of others. In addition, it gave them a desire to want to know what was happening and experiences they could refer back to when facilitators gave scientific explanations of these phenomena later. Social Engagement means participation in the big and small-group practices (e.g., interactional participation with others and conversations with other participants and facilitators). These experiences provided opportunities for participants to coordinate their activity and to collaborate. Such interactions often included participants' sensory engagement and helped participants recognize phenomena and pay attention to ways of conducting the activities. Cognitive Engagement means participants thinking about what they are doing and reflecting on what they might be learning. Participants' sensory and social experiences were the focus of what participants reflected on and affected the extent to which they engaged in these other dimensions of engagement. In addition, participants' sensory and social experiences shaped the extent to which they were able to reflect on their later experiences.

For each enactment, I identified episodes that seemed to promote or inhibit learning and, for each, I explored the dimensions of engagement and the relationships between those dimensions. In particular, I identified patterns in the types of interactions and experiences that seemed to be most important for fostering or inhibiting engagement and learning during that enactment. The case studies are crafted around those patterns.

From Enactment #1, I constructed Case Study #1, which explores dimensions of engagement that promoted cognitive engagement in activities (discussed in detail in Chapter 5). For example, I found that because participants wanted to "have their turn," they continuously monitored recipe preparation. This led to them noticing changes in the recipe artifacts, resulting in an interest in the role of some ingredients. This then promoted reflections on and conversations about scientific phenomena.

From Enactment #2, I constructed Case #2, which explores dimensions of engagement that promoted cognitive engagement during big-group discussions and dimensions of engagement that inhibited cognitive engagement during small-group activities (discussed in detail in Chapter 6). For example, I found that one-on-one interactions with the facilitator and other participants during big-group discussions promoted cognitive engagement. This led to participants developing a good conceptual understanding about how ingredients worked. In contrast, I found that when participants were disinterested in tasting or touching foods, it inhibited them from cognitively engaging in small-group activities. This led to participants not participating in planning activities that depended on their having preferences, which meant they did not gain experience using their conceptual understanding of how ingredients work to modify recipes. This is, in turn, created a gap between conceptual understanding and application of that understanding.

(RQ 2) What are the types of configurations that afford or inhibit these interactions and experiences in learning-by-doing learning environments?

Patterns identified in answering RQ 1 led to the need to answer this research question. To answer this research question, I looked across the two case studies to the affordances and constraints of the each environment that might be used to explain the conditions under which the ends occur. I found that physical layout, social configurations, and material configurations all played a large role in affording or constraining the occurrence of important interactions that led to deeper engagement in science.

I noticed that the physical layout of individual small-group workspaces (e.g., surfaces available to conduct work on) and the placement of ingredients, cooking utensils, and laptops influenced the placement of group members and the types of social interactions among group members. For example, participants working on different work surfaces with their backs to one another could not see each others' activity. This affected the ways that participants in small groups interacted with one another, the practices they developed for coordinating recipe preparation activities, and the frequency and topics of their conversations. When groups who worked farther apart from each other, or had more restricted visual and auditory access to each other, the participants noticed fewer cooking and scientific phenomena, and had fewer conversations about what they were noticing, resulting in fewer opportunities for making connections between cooking activities and science phenomena.

From this analysis, I identified some of the roles the physical layout, social configurations, and material configurations in the environment played in fostering or inhibiting interactions, and the subsequent learning and engagement that resulted. Additionally, I was able to propose a model that illustrates the relationship between: (1) the physical layout, social configurations, and material configurations, which are elements of the physical and social structure of the learning environment; and (2) the physical and social structure, and the interactions and experiences they promote and/or inhibit. This model was constructed from the data in Case Study #1 and was refined using the data from Case Study #2. The model draws on theoretical foundations in distributed cognition (Hutchins, 1995) to link the physical and social structure of learning environments to opportunities for learning and engagement. This model represents a hypothesis about the relationships and influences of the social, cultural, material, cognitive, and structural elements on engagement and learning.

1.5 Research Contributions and Implications for Design

Contributions of the research presented in this thesis include the following:

(1) It provides insight into the ways that engagement in learning-by-doing approaches creates opportunities for learning. I present a series of descriptive and explanatory case studies showing how participants' interactions and experiences promote and inhibit their engagement and learning.

(2) It suggests potential relationships between the physical layout, social configurations, and material configurations that promote and inhibit learning.

(3) It provides insight into the ways physical layout, social configurations and material configurations lay the foundations for the social, cultural, and cognitive aspects of learning-by-doing learning programs/environments through an illustrative model of the connection between the dimensions of engagement and the physical, social, and material configurations of learning environments, and the ways they influence engagement and learning.

Table 1.1 Summary of Research Questions and Contributions

Research Questions	**Contributions**
(RQ 1) What are the types of interactions and experiences that promote and /or inhibit learning and engagement in learning-by-doing learning environments?	Two descriptive and explanatory case studies that highlight patterns in interactions and experiences that promoted or inhibited learning
(RQ 2) What are the types of configurations that afford or inhibit these interactions and experiences in learning-by-doing learning environments?	A descriptive and explanatory list of social, material, and physical layout configurations that promoted or inhibited learning
	An illustrative model of the connection between the dimensions of engagement and the physical, social, and material configurations of learning environments

1.6 Overview

Part 1: Background and Chapters 2 through 4 introduce and highlight the background needed to understand the activities in the KSI cases, the studies conducted, and the methods used to collect and analyze the data. In Chapter 2, I provide additional context about KSI activities, activity sequences, curriculum, and assumptions about "doing", and expectations for learning. Chapter 3 is a discussion of prior findings on learning-by-doing and inquiry approaches to learning and raises questions about what it takes for the affordances of our designs to be taken up by participants. These questions foreshadow the discussion of dimensions of engagement that promote and inhibit learning and learning environment configurations that influence participant engagement in Part 2 of this thesis. Chapter 4 is the methods chapter. It describes the participants in the two KSI enactments analyzed in this thesis and the particulars of the enactments, including the physical layout, facilitator, and material resources provided. In addition, it presents the data collected and techniques used to analyze the data.

Part 2: Case Studies and Cross-Case Analysis - Chapters 5 through 7 introduce, present, compare, and discuss the findings from the analysis of the two enactments. Prior to presenting the case studies, I provide a brief overview of how to read the cases and some suggestions about what to notice while reading them. Chapter 5, Case Study #1, illustrates dimensions of engagement that promoted learning in Enactment #1. Chapter 6, Case Study #2, illustrates dimensions of engagement that promoted cognitive engagement during big-group discussions and dimensions of engagement that inhibited cognitive engagement during small-group activities in Enactment #2. Chapter 7, Cross-Case Analysis, identifies physical, social, and material configurations that influenced engagement in the two enactments.

In Chapter 8, the conclusions chapter, I answer my research questions, propose a model that organizes the relationships between the dimensions of engagement findings and the configurations, and discuss the implications and contributions of this thesis for both design and research.

PART I: BACKGROUND

In learning-by-doing activities, participants design and construct artifacts, either by hand, in virtual worlds, with digital toolkits, or by a combination of these means. Artifacts can take a variety of forms, including working physical devices or models, virtual models, plans, charts, drawings, narratives, and videos. Whatever their form, the intention behind artifact design and construction is that the goal of achieving a creation in a way that satisfies the learner and other participants will motivate participants to generate their own learning goals and to achieve the intended learning goals of activities. Additionally, the "doing" is meant to play a variety of roles:

- the bait or the enticement to promote extended engagement in activities and uptake of activity goals (Blumenfeld et al., 1991);
- reasons and opportunities to grapple with problems and come to solutions (Papert, 1980; Kolodner, Camp, Crismond, Fasse, Gray, & Holbrook, 2003);
- reasons and opportunities to engage in investigation and experimentation: planning and carrying out experiments, making observations of scientific phenomena, and reasoning about the results and drawing conclusions (Chinn & Malhotra, 2001; Blumenfeld et al., 1991; Kolodner et al., 2003);
- reasons and opportunities to iteratively build and debug ideas and mental models (Papert, 1980; Bransford, Brown, & Cocking, 2000; Vygotsky, 1978); and

- opportunities for engaging in competence targeted skills and practices, including tool use and the context to understand when such skills, practices and tools are relevant, important, and useful (Lave & Wenger, 1991).

Some of these roles are motivational roles, and some afford practice using targeted content and skills. But learning requires, in addition to having experiences, the experience of reflecting on them in ways that lead to learning. A big issue in making learning-by-doing learning environments work is organizing and facilitating activities so that participants see the value in reflection and remain engaged and excited even as they are reflecting in ways that might not always be fun.

A variety of approaches have been proposed that promote affective, cognitive, and social engagement in activities that afford learning:

a. Constructionism suggests that participating in design and construction of artifacts that participants are personally interested in have powerful affordances for discovering powerful ideas and promoting cognitive engagement and learning (Papert, 1980).
b. Project-based science learning suggests engaging participants in the kinds of design and construction of problem solving authentic to science has affordances for promoting engagement in scientific reasoning (Blumenfeld et al., 1991).
c. Problem-based Learning suggests that reflection on the cognition and other processing in solving problems and doing design promotes learning

how to solve problems and reason well through designing artifacts (Barron, Schwartz, Nye, Moore, Petrosino, Zech, & Bransford, 1998).

d. In the best of Inquiry-Based Learning, learners both ask question and do research to answer those questions which promotes an appreciation for the need to learn content and reasoning (Edelson, 1999).

e. Learning by Design (LBD) suggests that design challenges are particularly useful ways to help participants reflect on what they know and to use this knowledge to redesign. In addition, LBD suggests using activity sequencing to scaffold participants in inquiry practices and to establish community rituals that participants can begin to engage in themselves to ask and answer their questions. (Kolodner et al., 2003).

These approaches provide guidelines in four areas: design of activities, facilitation and support, resources, and creating a classroom culture conducive to collaborative sense making and development of dispositions towards cognitive engagement.

But we also know that the moment-to-moment interactions in a learning environment affect individuals' learning. A bothersome interaction with a peer or facilitator can lead a participant to stop paying attention or even walk off into a corner. Not being able to see a demonstration well because a participant is distracted by conversations with peers or otherwise engaged in parallel activities will cause a participant to miss experiencing an important phenomenon. Roth, McGinn, Woszczyna, & Boutonne (1999) tell us that even where a participant is sitting or standing in a room can make a difference in what is learned.

My goal in the research reported in this thesis has been to understand the roles that moment-by-moment interactions play in promoting and inhibiting engagement and learning, especially when participants are voluntarily participating in an activity rather than as a formal school activity. Each participant comes with different reasons for participating, and each will become excited by different activities. Understanding the role of participants' moment-by-moment interactions may help us design learning-by-doing learning environments that are more effective for a broader range of participants.

In Chapter 2, I present the design of KSI, including the activities and their sequencing, facilitation, and resources beginning with a description of a typical 10-week unit, and moving to present its overall design. In Chapter 3, I discuss the literature we drew upon to design KSI and the literature I use to analyze participant interactions and the influence of physical, material, and social configurations on learning in the case studies and cross-case analysis presented in Part 2 of this thesis. Chapter 4 introduces my methods for conducting this research.

CHAPTER 2

DESIGN OF KSI

Kitchen Science Investigators (KSI) was designed to scaffold middle school learners in reasoning scientifically and learning science content by connecting science to their everyday lives. To help participants in making the connection between science and their everyday lives, we decided to help participants understand how science could be used in the everyday activities of cooking and baking that many students at least participate in vicariously in their daily lives.

This chapter begins with an in-depth look at a typical 10-week KSI Enactment to provide a foundation from which to understand what participants experience when participating in KSI and how the design elements of KSI fit together. Next the chapter shifts to talking about the design of KSI, and it provides an overview of the science content we expected participants to learn and the scientific reasoning we expected participants to engage in. Then it provides detailed descriptions of the cooking and science activities, macro and micro activity sequencing, role of the facilitator, and material and digital resources of the program. Overall, the goal of this chapter is to provide the background needed to understand the episodes featured in the case studies and the cross-case analysis chapters in Part 2 of the thesis.

2.1 Overview of a Typical 10-Session KSI Program Sequence

KSI was designed as a once-a-week after-school program where participants got together for hour and a half to two-hour sessions to learn the science behind cooking. In this after-school program format, the 10 sessions were spread out over 10 weeks. We have also run KSI as a weeklong summer program where the 10 sessions were spread over five days.

We have developed two curriculum units to engage participants in science through the context of cooking: Leaveners and Thickeners. To help readers understand what KSI is about, this chapter begins by emerging readers in an overview of a typical 10-session program using the Leaveners' unit. The ten-week unit helps participants understand which ingredients make food rise and how each of those ingredients works. In this unit, participants prepare pizza to learn about the role of yeast, brownies to learn about the role of eggs, and cookies to learn about the roles of baking soda and baking powder.

2.1.1 Sessions 1-3 – Semi-Structured Session – Figuring out the Role of Focal Ingredients

Sessions 1-3 are introductory sessions. During each of these sessions, participants work to answer some driving question. Questions are about the role of a particular ingredient in a given recipe. These driving questions are presented in the context of a cooking advice column question like the one that follows:

Homemade Brownies
Dear KSIers,

We have a recipe for homemade brownies, but Christina and I like different types of brownies. Christina likes hers gooey, and I like mine cakey. We know you guys have investigated different types of brownies as well, so you may have your own preferences. We looked at the brownie mix box to get some suggestions about how to alter our homemade recipe. The instructions on the box say that you can use different amounts of eggs to get cakey or fudgy brownies. So we think eggs play a role in changing the brownies. Let's design an experiment to help us make recommendations for the amount of eggs needed in our homemade recipe for both gooey brownies and cakey brownies. As investigators, we can find out if eggs have other effects on brownies. As scientists, let's try to learn more about eggs to see *how* they work to create these effects.

Thanks,

Tammy and Christina

Each session begins with the KSI participants and the facilitator sitting in a big group reading the driving question from an advice column letter written to the participants. After one of the participants reads the letter, the facilitator helps the participants to abstract out the main question(s) the authors of the advice column letter are asking and the relevant information necessary for answering the question(s). The facilitator then leads the participants in a discussion about how to design an experiment to find an answer to the driving question. The driving questions highlighted in the letter above are: What role do eggs play in brownies? How do eggs work in brownies to create the different textures of cakey and gooey (i.e., fudgy)? How many eggs should someone use for a cakey brownie versus a gooey brownie?

Typically, the experiment is designed to figure out the role of a particular ingredient by either varying its amount or the type of ingredient used. Then the experiment is broken up into four variations, one for each group. In the brownie example, eggs are the focal ingredient, and participants decide that each group will make the recipe with a different number of eggs. One group will make the brownies with one egg, another with two eggs, another with three eggs, and another with four eggs.

After the experiment is designed, the participants break up into small groups of four individuals each and prepare one variation of the recipe. During this time, the facilitators help the participants to manage the logistics of preparing the recipe in a timely manner. They also model good observation skills so that participants will begin to notice important changes in their dish that are vital in helping them understand more about the role the ingredient plays in cooking and baking. In the brownie example, participants are encouraged to notice and record how the texture and composition of the batter changes as they add each ingredient. In particular, when they mix in the eggs they notice that the gritty texture created by the sugar in the melted butter and chocolate mixture becomes smooth. They also notice that prior to adding in the eggs, the butter separates from the chocolate when left sitting for a while. However, when the egg(s) are added, the mixture does not separate.

After the cooking experiment, participants then participate in a science experience to help them understand the scientific mechanism(s) behind the effects of the ingredient they were varying. This is generally done through an experiment, interactive demonstration, or related activity we (the designers) have chosen. While cooking, participants have noticed some phenomenon, and this activity is designed to help them understand the phenomenon. Facilitators prompt participants to make and record observations to share with their peers later in the big group discussion. In the brownie example, participants place the same amount of oil and water in four water bottles, and then add one to four eggs to the water bottles to replicate the variations represented in the brownie experiment. They shake these up to find that the oil and water still separate when they only add one egg. However, as they add more eggs, the mixture stays undivided longer. They also notice that as more eggs are added to the water bottle, more foam is created when the mixture is shaken.

Following the cooking and science activities, all the small groups come back together to share their results with one another in a big group discussion. Each group presents their results and any deviations from the experimental procedure. Then participants compare and contrast the different variations of what was cooked or baked to gain a better understanding of the role the focal ingredient played in the recipe. Following this discussion, the facilitator helps participants connect the science to the cooking activity by providing background information and explanations of the science underlying how the focal ingredient works. Participants then draw conclusions from the results and explanations and come up with their own rules of thumb and recommendations for making the recipe in the future, as well as answer the questions raised in the advice column letter.

In the brownie example, participants report what they saw when different numbers of eggs were added to oil and water. They also examine the four brownie variations. The one with one egg is flat and gritty. The one with two eggs is taller and smooth and fudgy. The ones with additional eggs are taller and fluffier (cakier). They propose that one egg was not enough to mix the brownie ingredients together well, and the facilitators tell them that eggs act as emulsifiers that hold different density materials together (e.g., oil from the butter and water from the chocolate). They notice that with more eggs, the brownies are taller and have more air pockets in them, and with more eggs; the egg, oil, and water mixtures have more bubbles and thicker foam. The facilitator tells them that eggs provide a flexible mesh/grid-like structural foundation that traps air incorporated into the batter from stirring. As the batter is heated from cooking, the air bubbles within this egg structure expand and harden. This information helps participants to recommend using two eggs for more gooey/fudgy brownies, and three eggs for more cakey brownies when using this recipe.

This process of reading the advice column letter, designing the experiment, preparing the cooking experiment and science experiment, sharing the experiment results, and listening to science explanations is repeated using different focal ingredients during the following sessions. Participants explore the role of yeast in one of these sessions, and baking powder and baking soda-type leaveners in another.

2.1.2 Session 4-8 – Recipe Perfection Exploration Days – Application of Focal Ingredient Knowledge and Understanding

After three weeks of exploring the roles of different ingredients, participants are then given the opportunity to remake a recipe they've already made, this time to achieve a personal goal, e.g., thinner pizza, thicker pizza, cookies that rise more or less. Based on what they learned in sessions 1-3, they choose the type and amount of leavening ingredient, either to meet a cooking goal or to explore what will happen. For example, participants in one enactment made pizza with different amounts of yeast to make thin and thick crust pizzas. They also made pizza with baking soda instead of yeast and cookies with yeast instead of baking powder.

Following this first exploration session is another semi-structured session, introducing them to another ingredient that is important in making food rise. In the Leavening unit, this ingredient is flour, and the participants make cakes from several different types of flour. They learn that gluten proteins in flour act as a structure that traps the air produced by the leaveners and stirring.

During the next two sessions, participants again choose to achieve a personal goal using any of the previous recipes. In one enactment, a group wanted to make chocolate-chip cake, and they varied the number of eggs in their recipe so that the batter would support the chocolate chips without crumbling. Another group wanted a moist and lighter cake and tried changing the type of flour. As in earlier weeks, small groups reported to the full set of participants their goals, what they did to achieve them (and why), what happened as a result, and what they learned.

2.1.3 Sessions 9 and 10 - Preparing and Presenting Foods and the Science Learned from the Foods

In the last weeks, there is even less structure and more choice. In these sessions, participants choose recipes to prepare for their families for the last session. The recipes they prepare may be variations on recipes they have tried or new recipes. The only rules are that they must be able to say why they are making their choice, and the ingredients need to be available. They also prepare posters to share with their families or create new stories or select stories about the perfecting process. They are encouraged to share explanations about the scientific mechanism(s) behind the focal ingredients of their recipes. At the end of the last session, they share their food and these explanations with their families.

2.2 Design Process

In designing KSI, we focused on five design components based on what the Learning Sciences and Cognitive Sciences literature suggested about how learning develops and what is needed to support it: (1) activities, (2) facilitation, (3) software scaffolding, (4) resources, and (5) activity sequencing. Thus, the initial design of the KSI program was based on the literature and our intuitions about what would be needed to help learners make the connection between the food they prepared in the program and the scientific principles behind the ingredients that made their food come out the way it did.

We took a design-based research approach to incrementally develop the program. A very important driver of the program's design was to meet the goals and learning needs of our participants. Throughout the four years we ran the KSI program, we were able to reach over 200 children who had a broad range of knowledge, skills, and attitudes with respect to science. In addition, participants came from a variety of public and private schools, both in suburban and urban settings. Keeping this diversity in the forefronts of our minds, we tried to design and redesign engaging activities that did not assume a participant's prior knowledge.

We recognized that this diversity meant that different groups of participants would have different Zones of Proximal Development (ZPD: Vygotsky, 1978), and each would require different levels and types of support. Thus, to design each enactment of KSI, we met weekly to prepare the cooking and science activities, devise specific facilitation goals, and to discuss the happenings of the prior session. Tamara Clegg, Janet Kolodner, and I were the regular meeting attendees across enactments. Other attendees included Human-Computer Interaction (HCI) and Computer Science (CS) Masters students who were working on the project at the time, which allowed us to consider a diverse set of perspectives and ideas. These meetings included discussions of the participants' learning and difficulties in the previous session. From this discussion we devised a list of specific facilitation goals for the next session that often included science content revisions to help participants make the connections between the cooking and the underlying science. In addition, we talked about what we were learning about participants' interests and goals.

We used this understanding to select recipes we thought would excite participants as well as meet the criteria for highlighting the science. We often used this time to brainstorm suggestions for addressing pragmatic issues like running out of time, focusing learners' attention on the science, and getting participants to reflect on their activities. Overall we addressed the following four recurring themes throughout the design of KSI: (1) ways to meet the learning needs and interests of our participants, (2) ways to help the learners make connections and draw conclusions, (3) supporting participants in thinking scientifically, and (4) developing strategies for addressing the pragmatic issues that arise during the course of a program session.

2.3 Science Content

Our goal in KSI is to help participants have the types of experiences where they have a need and a desire to want to learn the science behind why their food comes out the way it does. Then we make available science activities, demonstrations, and explanations that help them gain the knowledge they need to understand the mechanisms by which the ingredients they use make the food they prepare rise or thicken. We predict that the better their understanding of the scientific mechanisms behind these ingredients, the easier they will see connections between the results they desire in their recipes and the ingredients they can use to achieve those results. We also predict that, the more they are able to see the usefulness of science for answering their questions and fixing their cooking problems, the more they are able to see the relevance of understanding and relating science to their everyday lives.

We designed two units – one on leaveners and one on thickeners. Leaveners are ingredients like yeast, baking soda, baking powder, and eggs that make food rise. This unit is designed to help participants learn both life sciences and physical science concepts. Their experiences with yeast are designed to help them learn about yeast as a fungus that "eats" (i.e., metabolizes/ferments) sugar and produces carbon dioxide, alcohol, and more yeast. This suggests to them the need to understand what carbon dioxide is and ultimately what a gas is. They move on to discuss how yeast and humans are alike, both are alive and breathe, and both breathe out carbon dioxide.

Participants have opportunities to learn about acids, bases, and reactions through making cookies. They can learn about water and heat-based reactions in recipes that use double-acting baking powder. Double-acting baking powder has two chemical reactions. The first reaction happens when the double-acting baking powder is mixed with water, and the second reaction happens when it is heated. These two reactions create air bubbles in the dough and batters they are used to make.

There is also opportunity to learn about the anatomy of an egg, the role its proteins play in making ingredients in their recipes combine and stay together, and how proteins in egg whites make food rise. There is also opportunity to learn about changes in states of matter; they see water-based ingredients in batter (when heated) turn into a gas and evaporate, transforming liquid batter into a solid.

In the thickeners unit, participants use starches and grain flours like cornstarch, tapioca flour, white rice flour, and arrowroot. Participants learn about thickeners through preparing puddings, pie fillings, gravies, and sauces. Through preparing puddings with the four different types of starches, participants experience the different tastes and textures starches impart to foods, and the different degrees of thickness they can achieve with each. They have opportunities to learn that starches and flours are made up of lots of little starch granules that absorb and trap liquids and swell to sometimes 100 times their size when heated. They have opportunities to learn about the structure of substances, e.g., that starches are chains of glucose molecules, and that glucose molecules are composed of two types of smaller molecular structures that are shaped differently and therefore absorb liquids differently. This helps the participants to understand why some starches absorb more water than others. Through making strawberry no-bake pie fillings, participants can learn that by varying the amount of a starch you can control the thickness of different foods. They can learn about density and volume through a demonstration where different amounts of coco puffs, our model of starch granules, are placed into containers of 1 cup of water. Participants see that the more starch granules you pack into the water, the more difficult it is to stir, and thus, the thicker and denser the mixture becomes.

2.4 Scientific Reasoning

There are many opportunities for participants to learn to reason like scientists by participating in KSI. They use their content understanding to solve problems – ones that they are presented with and ones that arise while cooking. Driving questions presented at the beginning of a session often have more than one solution, and are intentionally designed to foster coming to conclusions based on knowledge and evidence. When their recipes do not come out as planned, facilitators help participants to use what they know to figure out why. Sometimes failure occurs because participants have incorrectly measured or forgotten ingredients, sometimes because they've forgotten entire steps. These "expectation failures" provide opportunities for participants to recognize the importance of following procedures exactly, measuring well, using the right units, and knowing how ingredients play their roles.

Each session begins with a big group discussion. During semi-structured days, the facilitators model for participants how to design experiments, answer questions, and solve problems, and participants engage in designing two types of experiments: experiments that vary the amount of an ingredient (e.g., the number of eggs or corn starch in a recipe), and experiments that vary the type of ingredients (e.g., baking powder versus baking soda in making cookies, or rice flour versus corn starch in pudding). They have opportunities to learn about independent and dependant variables, and the importance of controlling other variables. Participants collect and record data, using data as evidence to support conclusions, make recommendations, and make predictions and hypotheses. They carry out these practices and discuss them, providing opportunities to become proficient at them.

Participants experience that science is not just about learning facts, designing experiments, and/or following procedures but is also about exploring your curiosities. They experience how working with others, sharing results, and discussions help them to be better scientists. They experience the ways that what they already know helps them learn more. There are opportunities to learn all of these things.

2.5 KSI Design Components

KSI has macro and micro activity sequences. The goal of the macro sequencing of activities is to help KSI participants gradually construct mental models of the ways different ingredients work and gradually develop scientific reasoning capabilities. This sequence begins with semi-structured sessions spent planning, designing, and carrying out cooking and science experiments to learn about the role of several different kinds of leaveners or thickeners. It continues with less structured recipe-perfecting activities of participants' choosing where they use and refine what they learned earlier. Over time, these activities become progressively less structured.

The macro activity sequence provides the overall structure of activities in KSI. Within this overall structure, there are two micro sequences of activity for carrying out the semi-structured and recipe-perfecting sessions.

The semi-structured sessions serve several purposes. First, they serve as a place for facilitators to model: (1) how to plan and experiment to answer a question (2) how to design an experiment, (3) how to carry-out experiments, (4) how to make and record observations, and (5) how to analyze results across variations to draw out answers to the question. Second, the sessions helped to focus participants' attention on the science behind one particular type of ingredient, and the various effects they have on the end product. Third, the sessions are meant to pique participants' curiosity by providing a context for participants to "want to know" how to apply science and scientific reasoning to solving their own problems.

During recipe-perfecting days, participants are given more freedom to explore their interests as they relate to recipe preparation, and using the relevant science content they learned during the semi-structured sessions to perfect their recipes. The goal of these sequences is to provide an environment where participants can reflect on and use their understanding of the roles particular ingredients play when baking and cooking to improve the food's taste, texture, and appearance. In the first enactment we called these activities Retry Days; later in the second enactment we changed the name to Exploratory Days and/or Recipe Perfecting Explorations. The change in the name reflects the exploratory learning nature of the activities that went beyond simply retrying a recipe.

The Recipe Perfecting Explorations serve several purposes in supporting participant learning. First, the recipe perfecting explorations provide the participants with a context in which their questions and interests were important and worth pursuing. Second, these explorations positioned participants as experts in their recipes because of the multiple iterations it often took to perfect them. They were experts in the cooking techniques needed to prepare their recipes, and they experts in the science behind the ingredient used to perfect the recipe. Third, the explorations made visible that answers to questions are not always straight forward, and sometimes finding the solution requires repeated attempts to successfully achieve their goal.

Within each of the two micro sequences, the activities in KSI are broken up into small-group activities and whole-group activities and conversations. In a typical KSI enactment, the whole group is comprised of 16 participants. These sixteen participants usually divide into four small groups of four people each; these groupings are most often based on participants' desire to work with their friends. The small-group activities make up the bulk of the time participants spend in the program. These activities are geared toward providing hands-on and personal experiences with cooking and science. The whole group conversations are geared toward framing the small-group activities, making connections between the activities, and discussing the science behind the experiences the participants have in the small groups.

2.6 Semi-Structured Sessions: Small Group Activities

2.6.1 Cooking and Science Activities during Small Group Activities

The most basic components of the KSI program are the cooking activities and the science activities. The goal of the cooking activities is for participants to prepare several variations of a recipe by varying the amount or type of a particular ingredient to see the physical changes that result. Investigation of these physical changes would then reveal aspects of the role that ingredient plays in food in general.

Based on findings from Learning By Design (Kolodner et al., 2003) and our own intuitions, we anticipated that the cooking activities would create in participants a “want-to-know” with respect to why the ingredients played these roles. With this in mind, we designed the science activities to provide the basis for causal and mechanistic explanations of the physical change phenomena they witnessed in their food. These activities were designed to cause participant to wonder.

In the case of the brownies, participants mixed oil and water in a bottle, made hypotheses about what they thought would happen, then shook it up and let it settle. To some of the participants’ surprise, the oil and water that seemed to be homogenously mixed but then separated out after resting for 15-30 seconds, depending on how hard and long they shook their bottles. This surprise made them ask why the mixture separated out, which provided an opportunity for the facilitators and their peers to explain to them that oil and water have different densities that make them want to separate. The participants then added an egg to the bottle, shook it up, and let it rest for 30 seconds. They noticed the oil and water did not initially separate like it had when there was only water and oil in the bottle. This intrigued some of the participants and prompted them to ask why the oil and water mixture was not separating out like it had previously.

2.6.2 Facilitation in Semi-Structured Sessions during Small Group Activities

The cooking and science activities were created to excite participants' curiosity and prime them for wanting to learn more. Sometimes their peers knew things they wanted to learn, sometimes facilitators could provide explanations, and sometimes slides and other resources were available.

Thus, an important role facilitators play in KSI is providing explanations at the right level at the right times. Another is helping participants recognize when they already know something. Another is to point them to resources that might be helpful. Most importantly facilitators help participants become curious, since not all participants will become curious and ask questions on their own. Crowley and Jacobs (2002) suggest that parents do this all the time by pointing out things their child might find interesting, by providing small explanations of the phenomena to answer their questions. Parents then use these experiences as a hook for future learning on the topics they know their kid is interested in. Most importantly, we've found that providing short explanations participants needed to help them make connections between the phenomena they witnessed and the unseen science that created the phenomena helped to keep participants engaged.

Aside from helping learners make the explicit connections between the science and the cooking, the facilitators played the role of helping learners notice important things about the cooking and science experiments along the way. This help usually took the form of question asking, pointing out changes in their product throughout its development that were important for making connections later, and answering their questions.

In addition to scaffolding the science, the facilitator helped the participants manage the pragmatics of preparing recipes and cooking. This help often took the form of assistance with selecting the right measuring utensil, and using the right measuring or cooking technique. In addition they cleaned up spills and mediated group disputes.

2.6.3 Cooking and Science Resources for Semi-Structured Sessions during Small Group Activities

We recognized the value of situated knowledge and purposely kept ingredients in their original packaging to help participants recall experiences with and recognize what they already know about these ingredients, and to help them make connections to these ingredients when they are cooking or shopping outside of KSI. Thus, in some cases we may have only had one container of a particular ingredient that was shared across groups. In other cases where the resources were inexpensive, we would have one container of the ingredient for each group. We also kept the ingredients in the original packaging to encourage participants to look at the nutritional and dietary information. This came in handy when participants were trying to understand that eggs and flour were made up of protein. This information was also useful when participants were trying to make meaning of sugar as a type of starch. Lastly, because we were doing cooking and science experiments, we purchased the exact same equipment for each group to ensure there would be no effects from differing equipment.

For science explorations the amounts and types of materials we chose were very important for allowing participants to see the scientific phenomena. For example, the water and the oil in the bottles for the Eggs, Oil, and Water Exploration were specifically designed to match the amounts the participants used in their brownie recipes and to eliminate unnecessary barriers for making connections between the science activities and the cooking activities. In addition, we purposely selected clear plastic bottles and cups for all experiments so participants could get a 360-degree view of what was happening. In addition, we provided the participants with rulers, thermometers, and other tools for measuring physical properties of the phenomena they were experiencing. In addition, we provided tools for capturing gases that can often go unnoticed (e.g., bottles capped with balloons), and tools for measuring thickness (e.g., plate viscometers and cup viscometers).

The overarching goal for selecting and designing materials and tools was to make visible the science behind the ingredients participants were using in their recipes. Thus, we made sure that we always had these tools and resources available during each session so participants and facilitators could use them to further their understanding of the scientific phenomena they were investigating or exploring.

2.6.4 Cooking and Science Resources for Semi-Structured Sessions during Small Group Activities

During these small group activities, we designed software to help the participants record observations and later reflect on their observations. In the initial KSI program enactments, participants recorded observations and reflected on them using paper-based artifacts. The paper artifacts were designed to help focus participants' attention on using their five senses as investigative observations tools, record their observations, and share their observations with others. Figure 2.2 shows the Five Senses Chart that participants used during the first enactment of KSI to make the participants conscious about using their senses when investigating. We then moved to a poster-sized post-it that we placed on the wall to give participants more room to record observations. The headings on these posters evolved from step numbers with a short description of the step, to just the step number, both of which allowed all the small-groups to use the same poster to record observations on the same step. Then, because space was limited and participants did not have observations for every step, we moved to a poster title with the group's number which was used only by members of that group (see Figure 2.1 for an example of the posters groups recorded their observations on).

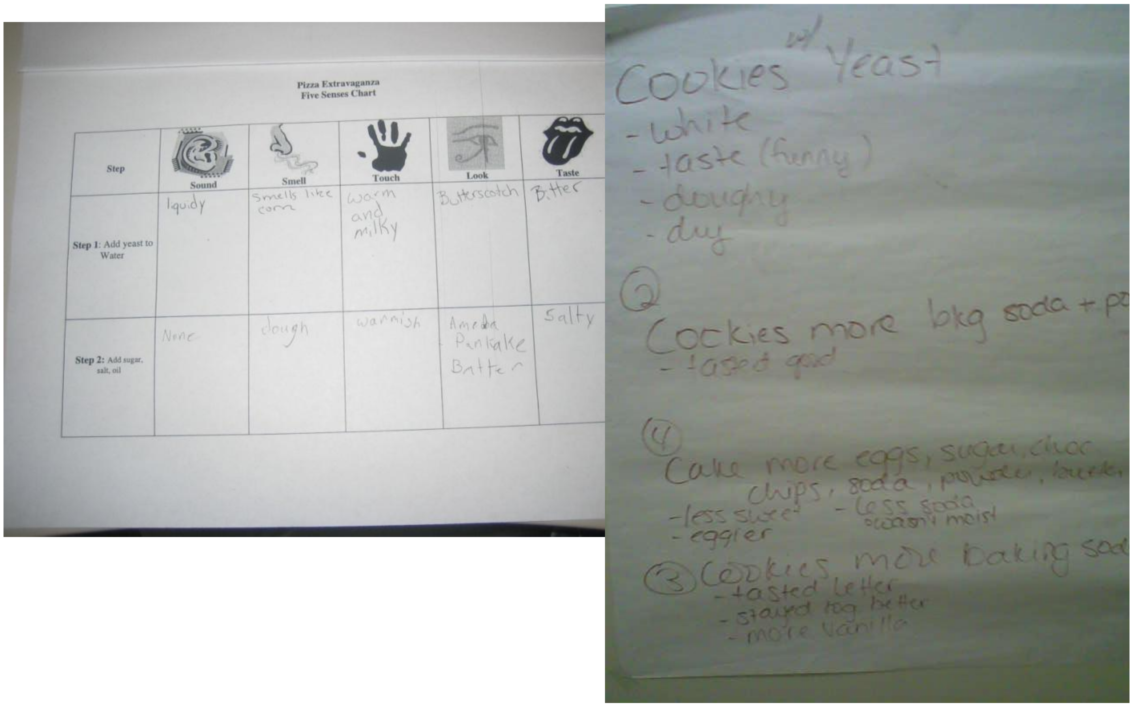

Figure 2.1 Five Senses Chart (left) and Poster (right)

Gardner, Clegg, Williams, and Kolodner (2006) found that, overall, participants were more engaged in the activities they were participating in than reflecting on their experiences. The paper summarized the conditions under which the paper-based media used led to successful reflection in action as being dependent on the location of the media and the level of cooking engagement in the activity. In addition, we found that paper was cumbersome and participants often did not want to refer back to it over time. Based on these results and our ultimate goal of trying to design software to support learning in learning-by-doing learning environments, participants in later KSI enactments, participants used software we created to streamline the process of recording and tracking observations (see Figure 2.2).

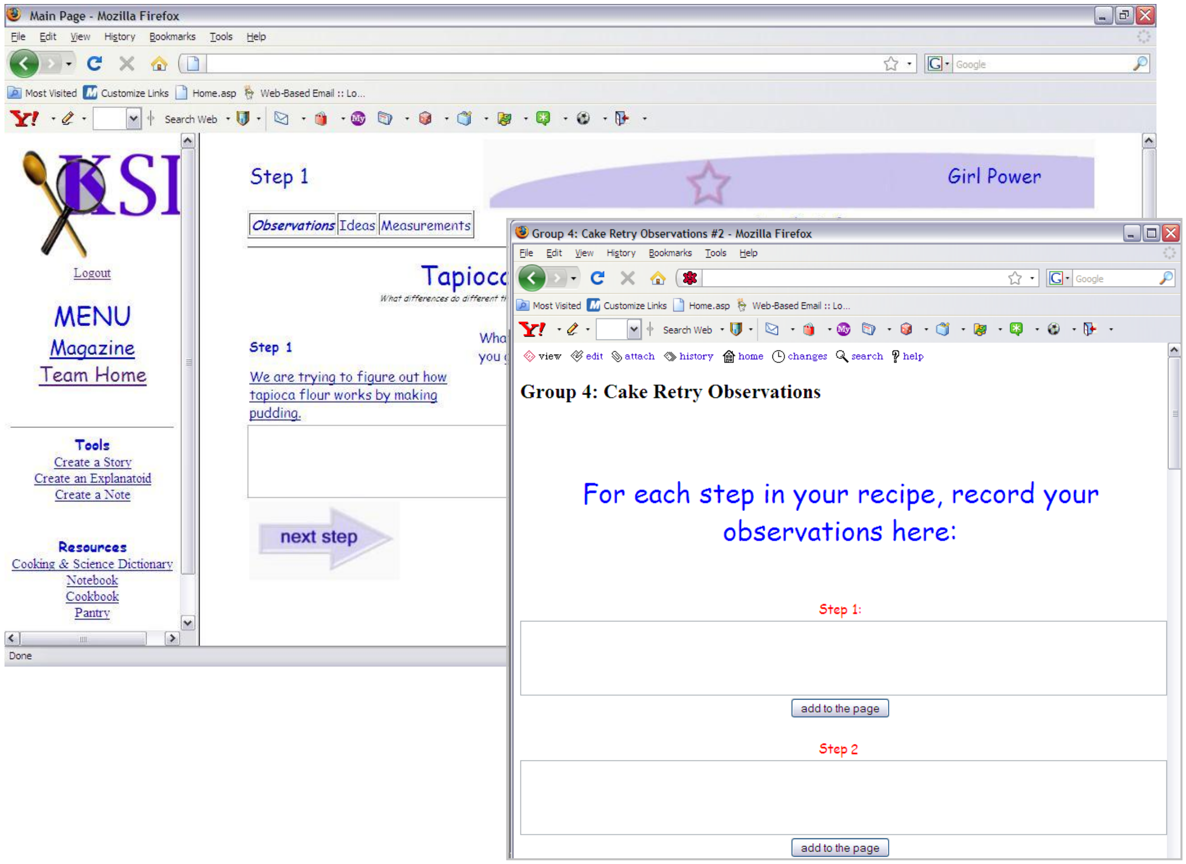

Figure 2.2 Current Version of the Recipe Annotation Tool (left-back) and initial version of the Recipe Annotation Tool (right –front)

We designed the software tools based on the practices we observed participants doing with paper, i.e., writing stories. Story Tool, a software-based tool, was created to help participants write stories (see Figure 2.3, left). The Story Tool provides space for participants to tell the story of their experiences. We provided minimal scaffolding that simply reminded them of the structure of a good story in order to allow them to share what they felt comfortable writing.

We also added the Explanation Tool (see Figure 2.3, right) to help participants make connections between the science and the cooking by providing explanations. The

Explanation Tool was based on our desire for the participants to create short explanations that pulled together everything they understood about the science behind their cooking. The original idea was based on Crowley & Jacobs' (2002) concept of an *Explanatoid*. *Explanatoids* are short explanations that parents tell their young children when they ask a question. In general, during early activities, facilitators help participants create *explanatoids* during discussions, and then, in later sessions, participants take over this process with the help of the Explanation Tool. This software underwent several developmental phases, so participants over the years interacted with several different software interfaces.

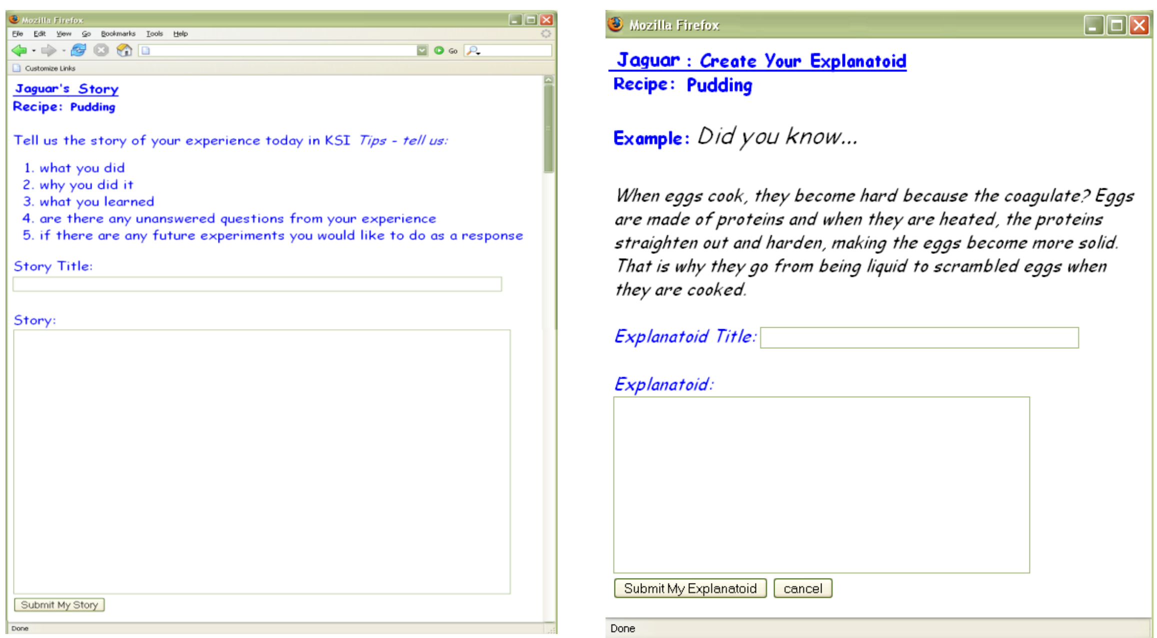

Figure 2.3 Story Telling Tool (Left) and Explanatoids Tool (right)

2.7 Whole Group Activities during Semi-Structured Sessions

2.7.1 Big Group Discussions during Semi-Structured Sessions

The whole group activities include cooking experiment planning and discussion of results. The major features of this activity are the conversations participants and the facilitators have before beginning the small group activities and following the small group cooking and science activities. The discussions are generally guided and directed by the facilitator. The "discussion of results" usually happens while tasting and investigating the food the groups have prepared during the small group activity time. During these discussions, the facilitators have the participants share their experiences preparing the recipes and talk about potential errors that might have affected the end product. In addition, the facilitator helps them connect back to the initial conversations the large group had while planning the experiment.

2.7.2 Facilitator for Semi-Structured Sessions during Whole Group Activities

During the whole group conversations, the facilitator provides the entire group of participants with the science explanation behind the role the target ingredient played in their cooking experiment. The facilitator also models for the participants how to design experiments, how and what questions to ask, and things to be careful about while cooking, running the experiments/investigations, and collecting data.

2.7.3 Software for Semi-Structured Sessions during Whole Group Activities

For big group discussions, participants used software to discuss contextualized problem statements presented to them through the context of the Cooking Advice Column Questions researchers wrote. After reading a column question, the facilitator would lead the group in filling out a KWL board. The board featured three questions that asked them (1) what they Knew about the problem space from their own personal experiences and from the column question; (2) what they Wanted to learn; and (3) what they Learned from their experiences. The KWL chart is used in reading and science classrooms to help learners focus their attention on important parts of the text and problems as they do projects to solve them. This feature was used a lot during earlier enactments of KSI, but phased out after implementing experiment design pages into the software. These experimental design pages were created to help learners collaboratively plan experiments that were spread across the groups. We specifically designed this aspect of scaffolding into the software to make explicit to the participants the process for planning an experiment, and the things they should pay attention to. The facilitator was already helping the group collaboratively plan experiments, but we wanted to make this process visible and explicit to the learners.

When we shifted to using the KWL feature of the technology, we found that it took a long time to use and thus, for pragmatic reasons we shifted our attention away from having the participants in later studies use the KWL board to dissect the question to focusing their attention on planning and designing experiments. We shifted to planning and designing experiments because we found that participants often forgot the plan and the need for being careful about measurements and following the recipe, so that we would have comparable end products. Thus, in later enactments, the learning focus shifted slightly away from analyzing the end products of the foods, to understanding the roles particular ingredients played in the recipes, to measuring and running variations of the recipe with as much precision as possible. As a result, the focus of facilitation during small-group activities and large group conversations shifted as well.

The software was also used to help participants tell stories about their experiences during big group discussions. While comparing and contrasting the foods participants made, we brought up their observations, results, stories, and explanations for them to share as well.

2.7.4 Resources for Whole Group Activities during Semi-Structured Sessions

During these big group discussions we tried to use as many participant-created artifacts (e.g., brownies, cookies, pies and science experiment artifacts) as were available to help participants make connections. We found that referencing past artifacts was important for helping participants remember and reflect on their experiences. It also served to help participants compare.

We selected recipes and ingredients to vary that would show the most dramatic differences when altered to assist in making changes in the phenomena visible. We also spent a lot of time selecting the materials participants would use to run the experiments. For example, we used 1.5 quart clear plastic bottles and cups so that participants could see what was going on in the bottle/cup. Again, the point is to make the invisible science phenomena in recipe preparation visible (e.g., metabolic reaction of the yeast and the sugar, acid and base chemical reactions of the baking soda and baking powder, and structural properties of eggs with oil and water). We used balloons to capture the air the leaveners produced. Participants used these resources to get an inside glimpse of what was going on in their recipes as they prepared and cooked it. These resources and artifacts were then left on their workspace so they could observe changes overtime, and begin making connections between the science activity and their cooking activity.

2.8 Recipe Retry and Exploration Days

2.8.1 Recipe Retry and Exploration Day Activities

During Recipe Retry and Exploration days, participants planned a recipe they would like to prepare again, but changed the type of leavener or the thickener. The ingredient change was based on their previous experience with that ingredient, the results it yielded, and the match between that ingredient and the end goal of the new product/dish. Participants prepared their recipes according to their plan and revised their understanding.

2.8.2 Facilitation during Recipe Retry and Exploration Day Activities

During these exploratory days, facilitators helped participants adapt recipes based on what they had learned during the semi-structured days to participants' recipe perfection goals. The facilitator reminded them of what they knew, asked them questions about what they were trying to achieve, and helped them make changes to their recipes. Facilitators often helped participants through this process by reminding them of what they learned previously. At times the facilitator would devise science activities so the participants could revisit what they learned, and/or test out their ideas and hypotheses before they changed their recipe.

2.8.3 Paper-based and Software Scaffolding during Recipe Retry and Exploration Day Activities

Participants were given planning sheets to help them think through the decision making process. These planning sheets asked them to state their goal, what they would be changing in their recipe to achieve that goal, and what evidence they were basing their prediction on. Toward the end of Enactment 1, we shifted the planning from the paper-based resources to web pages with text entry boxes (see figure 2-5). To help participants fill out the planning sheets, they also had access to the observations and results of previous cooking activities they've done.

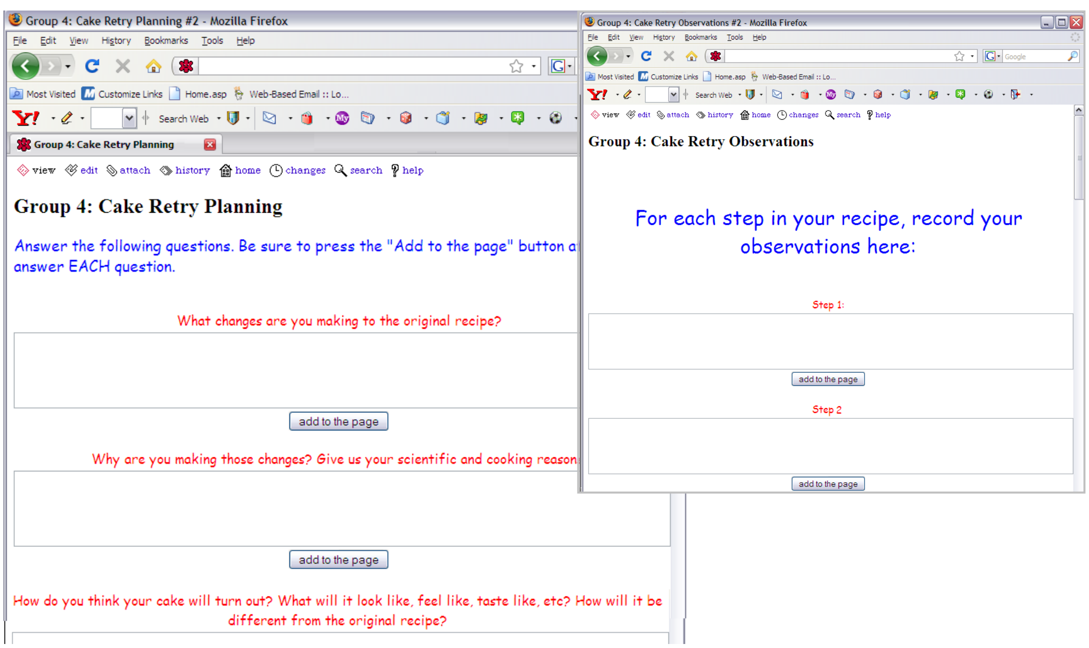

Figure 2.4 Retry Day Planning and Observations pages

We, the researchers, added these recipes to the software so that groups could take advantage of the software's observation tools and link their stories to their recipes. In Enactment 2, we designed the Recipe Change Page in Figure 2.5 so that learners would have a copy of the original recipe while making alterations to meet their preferences. In later software implementations, this page was redesigned with scaffolding to help learners identify which changes needed to be made to their variation of the recipe by having two pages; one for group planning of the experiment and the variations (see Figure 2.6, left back), and another that highlighted the goals of the experiment and the changes they needed to make to their variation of the recipe (see Figure 2.6, right front). We did not automate the recipe variation changes because we wanted to force the participants to reflect on what changes they were making to the base recipe and why.

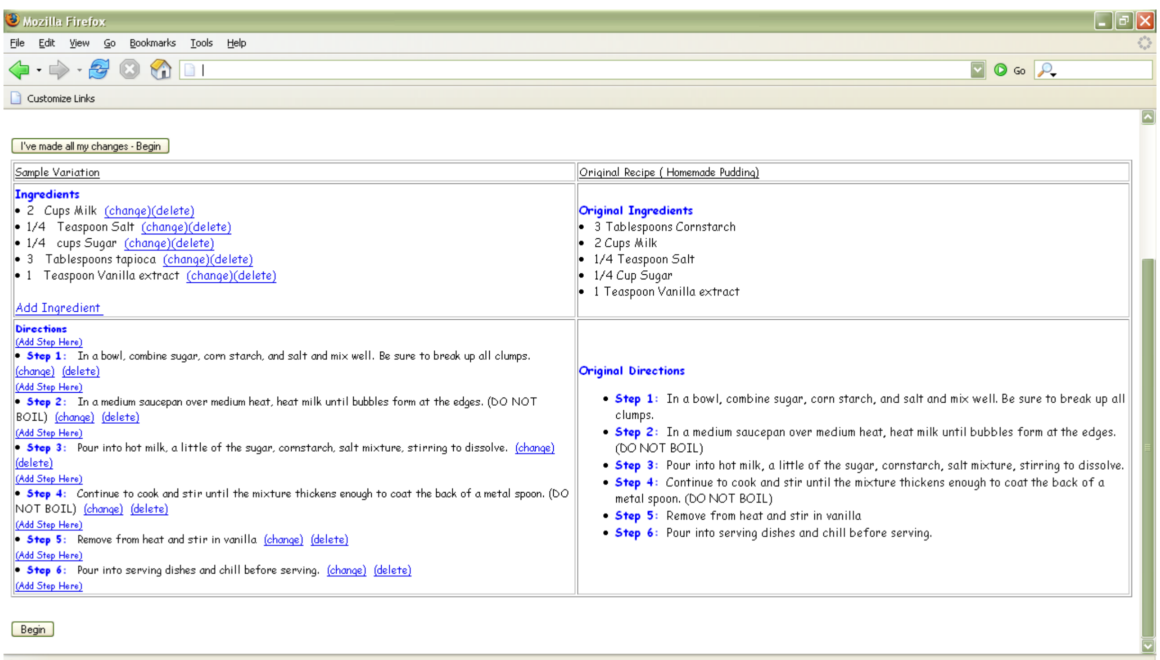

Figure 2.5 Recipe Change Page

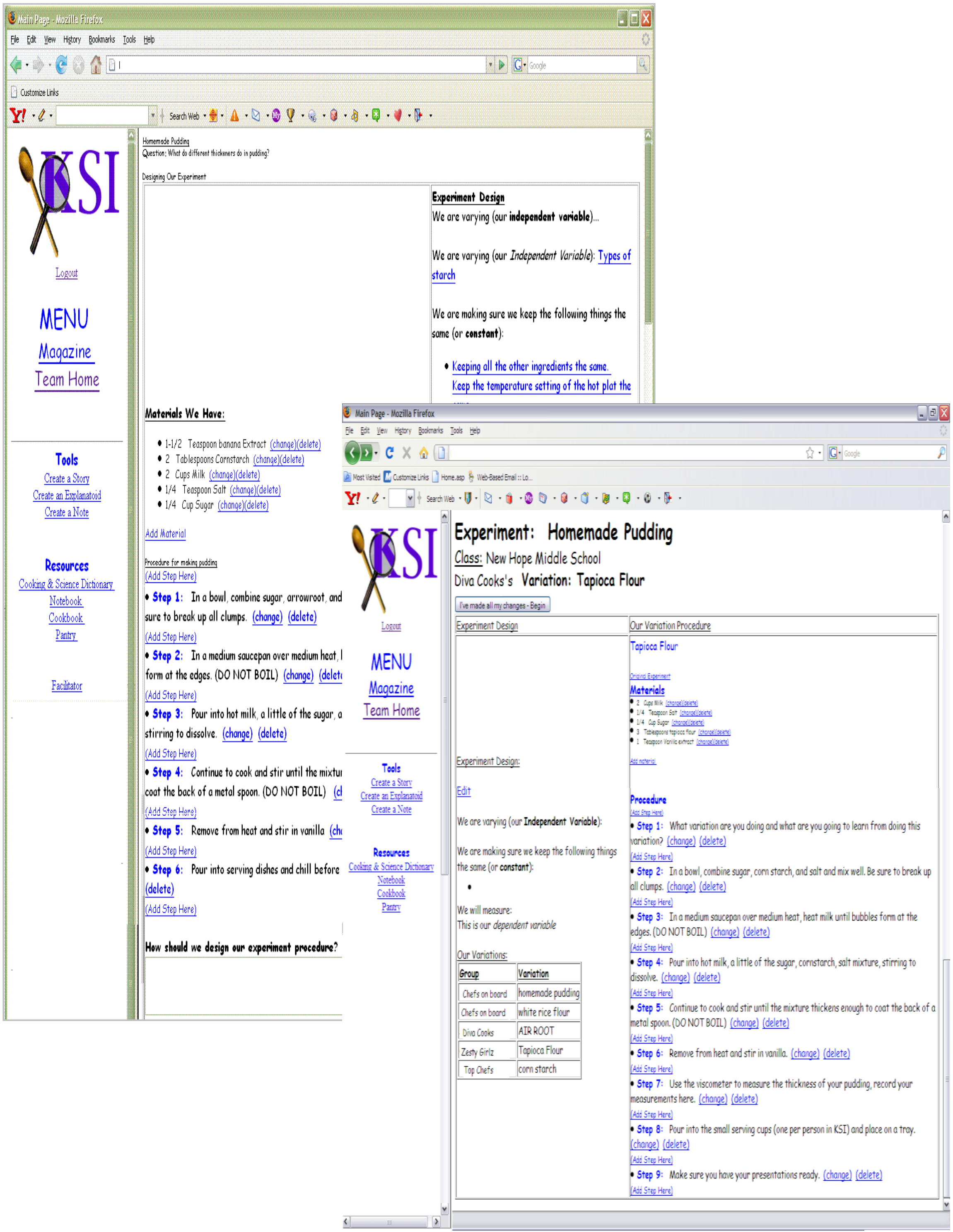

Figure 2.6 Group Experiment Planning (left-back) and Small-group Recipe Variation Change (right-front) pages

2.8.4 Resources for Recipe Retry and Exploration Day Activities

To help participants fill out the planning sheets, we ensured that they had access to materials to create new science explorations, samples of foods and experiments they've previously made when available, and prepackaged foods like pudding, Jell-O®, cheese sauce, tortillas, cakes, tarts, parfaits, jams, and candies to help them define their preferences for the taste and texture of their foods. At times they were also provided with pictures from their previous experiences.

2.9 Chapter Summary

This chapter has provided an in-depth look at a typical 10-session KSI Enactment both from the participant perspective and from the design perspective. It provided overviews of the science content we expected participants to learn and the scientific reasoning we expected participants to engage in. It provided detailed descriptions of the cooking and science activities, macro and micro activity sequencing, role of the facilitator, and material and digital resources of the program. Overall, the goal of this chapter was to provide a sufficient background to understand the episodes featured in the case studies and the cross-case analysis chapters of this thesis.

CHAPTER 3

BACKGROUND AND LITERATURE REVIEW

The cognitive and learning sciences literatures provide theories about cognition and social cognition that can be used for framing activities, social supports, and resources to promote learning. Designers of learning-by-doing approaches and programs take into consideration these theories and learners' interests when they are designing both learning environments and supports for implementing these learning approaches. However, when these designs are implemented, participants do not always take on the intended learning goals as expected or get out what the designs intended. For example, in KSI we designed the cooking activities to pique participants' interest in the sciences, but we have found that participants are often interested in the aesthetics of the dish more than they are in the science behind how it works.

This gap between the intentions of the design and the realization of the design's goals suggests that in addition to our current design considerations of learners' cognitive needs and personal interests, we need to consider how to help individuals take up the intended affordances for engagement and learning. In particular, I believe that we need to take into consideration under what circumstances participants will engage in the structural elements (e.g., activities, activity sequences, and resources) designed to help them engage in the cognitive processes necessary to achieve the learning goals of a given program. Therefore, I make a big claim in this thesis, a claim that drives all of the work I report:

> To fully realize the affordances of learning-by-doing learning environments, we need to design those experiences taking into consideration not only learners' interests and cognitive needs when we choose the activities, their sequencing, the social supports and the resources that will afford learning. We also need to know how to help individuals take up the affordances designed into the environment and design.

To support this claim, I will, in this chapter, present the cognitive and social foundations that undergird the design of KSI. Then I take into account the interests, social and cognitive needs of participants using those foundations to raise questions about how learning happens in practice in these environments. The literature provides theory about how learning might happen; I am aiming to add to learning and design theory about the circumstances in which participants engage so that the designed affordances are taken up and the learning goals are realized. Then I highlight the steps towards this goal that have already been taken by others.

3.1 Foundations for Designing Effective Learning-by-Doing Learning Environments

Learning-by-doing activities play a number of roles in providing opportunities for participants to engage physically and cognitively in learning. From my reading of the literature, almost all effective learning-by-doing approaches use similar design structures for supporting the cognitive and social needs of learners:

(1) Designers select a <u>disciplinary focus</u> and identify <u>learning goals</u> (e.g., targeted science content, science practices, and/or inquiry) for the learning-by-doing learning environment and activities

(2) They identify <u>cognitive processes</u> that support the targeted learning goals (e.g., seeing targeted phenomena, reflection, opportunities for carrying out practices,

(re) indexing, (re) constructing mental representations, assimilation and accommodation of information, etc).

(3) They select <u>structural elements to support the cognitive processes</u> needed for achieving the learning goals (e.g., content materials, activities, resources, activity sequencing, and facilitation).

(4) They also consider the <u>affective and social affordances of structural elements</u> that need to be included to realize the cognitive goals (e.g., having participants work in small groups, selecting topics that are personally interesting to participants, etc)

While I numbered the elements in the list, designers can perform them in any order with some of the elements having more weight than others depending on the overall goal for the design.

KSI is a design-based research project that builds upon a number of approaches to learning and theories of learning. In the following section, I will use this structural framing to discuss several learning-by-doing approaches and the social and cognitive theories that undergird their designs. In particular, I will describe the approach, the learning goals, the cognitive processes they are trying to engage, the structural elements they use to engage participants cognitively, and the social and affective elements they include in their designs. I will then highlight the aspects of these approaches that we incorporated into the design of KSI. Last, I will raise questions about what is required of participants to achieve these goals.

3.1.1. Constructionism – Computer Clubhouse

Constructionism (Papert, 1991) and Social Constructionism (Bruckman, 1998; Kafai, 2006; Resnick, Bruckman, & Martin, 1996) seek to provide the types of tools that help children engage cognitively with sophisticated ideas and to begin building mental models. Papert (1980) based the Constructionism philosophy on the work of Jean Piaget, specifically his idea that people actively construct their understanding rather than being passive receptacles of knowledge. Often, constructionist approaches to learning provide computational tool kits on the premise that people learn particularly well when constructing their understanding through constructing artifacts. Furthermore, they believe that when learners construct personally meaning artifacts and engage with them long enough, they make epistemological connections to the intended content.

Traditional Constructionist approaches focused on an individual's interactions with tools while peripherally recognizing the roles of other people in the learning environment. Social Constructionism approaches supported groups of learners to engage in construction activities together. Both social and traditional Constructionism value social interaction as an opportunity for learners to show off their artifacts with an audience that validates their meaningfulness.

Overall, the role of the materials and tools in this approach assume internalization of concepts and processes that are defined and constrained by the design of these tools. Likewise, the role of social interactions is seen as a motivational medium for learning.

Computer Clubhouse is an example of a Constructionist project. It is a network of after-school computer facilities that serve children aged 10-18. The goal of the program is to help bridge the digital divide by providing computer access and mentorship to underserved children to help them build technological fluency. This technological fluency is achieved through helping participants explore their own ideas, develop skills, and build confidence in themselves through the use of technology.

The Computer Clubhouse's learning model is built off of 4 driving principles: (1) Learning by designing, (2) following participants' interests, (3) building a community, and (4) building trust. To leverage participants' interest, the Computer Clubhouse provides participants with computers, music mixing equipment, graphic design programs and other computational resources/digital tool kits for them to explore their ideas through constructing artwork, animation, simulations, music videos, and robots (Resnick, 2002). For example, in the Computer Clubhouse, a participant who wants to create a demo tape to promote himself as a rapper, can learns enough about the mixing equipment, microphones, and beat maker to create his own music track (Resnick, 1998). They may or may not learn about the musical notes, tone, pitch, and so on that one could also learn from the activity, but they learn how to use the technical equipment to record, arrange, and edit their demo.

In addition to creating artifacts, Social Constructionism suggests that sharing artifacts with a larger community is a powerful way of legitimatizing the epistemological value of the work participants do in the clubhouse. Resnick, Bruckman, and Martin (1996) suggests that having an artifact to share is often an important motivator for participants to share knowledge and experiences. Having an artifact present may promote others to comment on the artifact or ask questions of the artifact creator. This provides participants with the opportunity to share the story behind its creation and what they learned while creating it. Such sharing provides opportunities for participants to reflect and reconfigure what they know and in the telling and re-telling they realize things they had not before. Such sharing helps reinforce the importance and value of the activities that participants are engaging in because it adds value to the artifact and their doing it when other people care about what they have done. This is often realized in designs by ensuring that there is an audience for participants to share with both caring adults and peers (Resnick, Bruckman, & Martin, 1996).

KSI draws on Constructionist and Social Constructionist approaches to learning by supporting learners in constructing personally meaningful artifacts through which they can build epistemological connections. In particular, we leverage participants' interest in cooking to help them engage in scientific explorations of ingredients and the roles they play in tailoring recipes to participants' liking (Clegg et al., 2006). For example, in one of our enactments, many of the participants told us how much they enjoy nachos and cheese. During one of the retry days in the Thickeners unit, we helped some of them figure out how to make a nacho cheese sauce from scratch and decide what combination of starch thickeners would produce the right texture.

After KSI participants have perfected their recipes, we give them tools to write their own stories and explanatoids, short explanations of the science phenomena they've witnessed. These stories and explanatoids are then showcased on the front page of the Cooking and Science magazine we create for the participants to share their experiences. These experiences are also shared in big group conversations while reviewing the foods that the participants created. Often participants are just excited to share what they are doing or have done. In these ways, KSI tries to ensure that participants have a broader audience with which to share their KSI knowledge and experiences.

3.1.2 Case-based Reasoning and Learning By Design

Case-based Reasoning (CBR) is a theory about reasoning that suggests that people make inferences or reason about the world to solve problems based on internal cognitive representations, scripts and cases (Kolodner, 1994; Kolodner et al., 2003). Scripts are cognitive representations of social rituals and practices of a community that provide templates for how a ritual or practice is enacted and tell a person what to expect in that situation. Cases are personalized versions of scripts based on a person's previous experiences enacting the scripts in the past. These cases may include personalized details of what one did and why as well as mistakes they made and things they would like to do differently the next time. A case-based reasoner might solve problems by remembering previous situations similar to the current one and base his/her solution to the current problem on a solution that worked in the previous situation (Kolodner, 1994). In addition, CBR suggests that not only do people reason with their internal cases but they can also reason with external cases of others solving similar problems.

In CBR, indexing and expectation failure are seen as fundamental mechanisms by which people access and revise their internal cases for doing things. Indices suggest when and how a particular case should be used or referred to. Expectation failure suggests when the explanation in a case should be revised with the information gained from the present experience (Schank & Abelson, 1977).

Learning by Design (LBD) is a project that incorporates CBR principles in the design of a classroom science learning approach. LBD is a classroom approach to engaging middle school learners in science and science inquiry through designing (Kolodner et al., 2003). In LBD, learners design artifacts (e.g., cars and tunnels) to solve a design challenge (e.g., build a car that can go 15 feet and deal with different terrains). Since learners do not have enough previous experiences building these artifacts to understand the key components that affect their performance, LBD provides two types of opportunities for learners to get this knowledge. First, it allows participants to have their own experiences constructing the artifact and seeing what happens, and sometimes it provides learners with expert cases of others who worked on designing solutions to similar problems.

In this way, science learning is driven by participants' need to understand why a particular design works or is not successful at meeting a particular design challenge. This requires participants to reflect on what they know and to use that knowledge to redesign their artifacts to successfully complete the challenge. For example, participants use what they know about forces, motion, and friction to design and redesign cars that travel a certain distance or can complete a particular type of course. LBD draws heavily upon CBR's suggestion that cognitive engagement and reflection on one's experiences and learning happens when people have previous cases to draw upon and to base their decisions on and expectation failures in the application of the lessons learned from the cases that make them revise their cases or scripts.

In KSI, we draw on the suggestions of CBR and LBD to inform the design of activities, their sequencing, and the shifting of social arrangements (i.e., big-group to small and back) to help participants know what to cognitively focus their attention on and to know how to participate in KSI activities. Thus, each session of KSI has the same format: (1) Big group conversations that focus all the participants' attention on the same problem or set of problems. (2) This is followed by small-group activities where participants try out their solutions or prepare their variation to the recipe. And (3) then the groups come back together to have a big group discussion about what they found out and together the group draws conclusions.

We structure the semi-structured activities to help participants build cognitive representations of how ingredients work and what to expect when they use them by allowing them to make and see several variations of a recipe and so that they can build their own cases and expectations for using these ingredients and preparing recipes. In addition, when participants are planning cooking experiments we help them select variations that run the spectrum of highly successful to terrible to provide a contrast that makes them ask why. Thus, we build in expectation failures to help participants reflect upon their experiences and revise their representations of the cases they've constructed. We do this so that later participants can draw on these experiences, as well as others they may have had outside of the program, to inform the types and amounts of ingredients they use in a recipe when they adapt it to their own taste and texture preferences.

We hope that the act of constructing a personally-tailored dish will motivate participants to reflect on what they are doing and how it comes out to build cases of their experiences. And to further insure that they are reflecting, we ask them to present their experience to the larger group, as LBD suggests. Furthermore, we hope that participants will notice when their recipes do not come out as they expected and that they will examine both their cases for how to prepare these recipes and the expected outcomes and their recipe artifacts/dishes to revise own cases about what led to recipe success and failure and the how ingredients work and what to expect when using them. And to further insure that, we provide the story telling and explanatoid tools that ask them to make their reasoning and what they learned explicit.

3.1.3 Knowledge Building

Knowledge Building is another approach to learning that influenced the design of KSI. Knowledge Building (KB) is a learning-by-doing approach based on the notion of idea-improvement as a means of advancing the community's understanding (Scardamalia & Bereiter, 1996; Scardamalia, 2002). It is based on the philosophy that knowledge arises from efforts to understand the world. The learning community picks a topic to learn about and then each learner does their own research through first-hand experiences with the topic or through researching the topic and writes up their ideas about what they found and how that topic works for the rest of the community.

While learners contribute individually to this repository, all idea are communally shared, owned, and developed for the sake of advancing the knowledge and understanding of the community as a whole. The ideas that are contributed can be at varying levels of detail and specification to support the collective improvement of ideas: "the [learning] culture must be of psychological safety, so that people feel safe in taking risks–revealing ignorance, voicing half-baked notions, giving and receiving criticism (Scardamalia, 2002, p. 9)." Furthermore, learners contribute knowing that all ideas are treated as improvable by anyone in the community. So learners expect to individually as well as collectively revisit and improve their ideas about any topic. Thus, learners are not passive consumers of knowledge but active producers of knowledge as such learners construct a communal knowledge repository.

For Knowledge Building to work, participants must take on *collective cognitive responsibility*. This requires a great deal of individual intentional effort from each learner. That is, each learner takes on the responsibility to develop their ideas either through researching the topic or designing artifacts to test them and then reports back to the group what they have learned in the form of writing a note in the Knowledge Building repository. Next, learners have to read the ideas of others and comment on them or improve them in some way. In addition, participants make connections between the different ideas and formulate notes about the relationships. With each of these steps the community collectively refines their understanding of the topic.

Thus, individual as well as team contributions are prized as team members produce ideas of value to others and share responsibility for the overall advancement of knowledge in the community. This requires that all participants feel like legitimate contributors and share the goals set forth by the community and that individuals take pride in advancing the knowledge of the community. This form of cognitive responsibility requires Epistemic Agency. Epistemic Agency is the process that participants engage in, "to set forth their ideas and negotiate a fit between personal ideas and ideas of others, using contrast to spark and sustain knowledge advancement rather than depending on others to chart that course for them (Scardamalia, 2002, p.10)."

Overall, Knowledge Building is a way of thinking, a disposition that is cultivated that pervades participants' mental lives in and out of school (p. 11). As such, research on Knowledge Building communities makes recommendations about supporting the cognitive activity of a classroom culture of inquiry and reflection through writing, which necessitates intentional collective and individual cognitive responsibility. However, intentional collective and individual cognitive responsibility is important not to just in the construction of written artifacts but also in the construction that is required in all learning-by-doing approaches for the affordances of the design to be realized.

KSI has taken into consideration the suggestions of KB in that we do not set or expect that everyone will have the exact same experiences or know the exact same things, especially since KSI is in an informal context and is not governed by mandated curricular standards. Thus, we structured the KSI activities around a particular ingredient and set of questions to provide participants with the experiences that would allow them to develop a sense of ownership of their recipes and knowledge gained from those experiences and to develop accountability to others to share what they know. We use big group discussions to structure the social environments to help the various individuals in the learning environment learn to draw on one another as resources. In addition, we have tried to use the stories and observations that participants put into the KSI Observation, Story, and Explanatoid tools to build a communal repository that participants can refer back to like a case library and to help them to build upon their previous ideas.

3.1.4 Knowledge Integration Environment

Knowledge Integration Environment (KIE) is a middle school classroom approach to science learning where participants collaboratively work together to answer science questions (Bell et al., 1995; Slotta, 2004; and Linn, 2006). KIE environments use networked resources and software to help participants find, integrate, and use scientific evidence to answer scientific questions (e.g., does light travel forever or does it die out?) Furthermore, the goal of KIE environments is to help participants develop a "propensity toward integrating knowledge in general" (Bell et al., 1995, p. 14).

KIE suggests that revisiting, connecting, clarifying, and improving understanding are necessary for learners to integrate new knowledge into their existing knowledge (Linn, 2006). Where the focus of Knowledge Building is on the communal construction of new knowledge and understandings, Knowledge Integration warns us not to ignore the individual and the importance of individuals revisiting their own conceptions. KIE focuses on what cognitively happens to individuals when they learn. The focus in KIE is primarily on making thinking visible and connecting experiences and understanding. Like LBD, KIE suggests that activities and activity sequencing be structured to provide opportunities for learners to revisit what they have learned.

In KSI, we also designed the sequencing of activities such that there would be multiple opportunities for learners to revisit, connect, clarify, and improve their understanding as in KIE environments. This primarily appears in the sequencing of activities where learners are given the opportunity to engage in a cooking activity that provides a basis for the science that gets explored through a related science activity that increases the visibility of the science behind the cooking. The sequence of activities is also designed to help the learners connect both their cooking and science experiences together and to improve their understanding. The influence of KIE in KSI is also seen in the revisiting of the central concept of leavening or thickening over 10 weeks in multiple recipes and science experiments and explorations. In KSI as in KIE, we also use written reflection within small group activities to facilitate dialogue and make the thinking of each of the group members visible. In large groups, we use encourage the sharing of the edible artifacts participants designed to provide opportunities to make their thinking visible and to revisit concepts.

3.1.5 Islands of Expertise

Islands of Expertise is a theory of how very young children learn through experiences and interactions with their parents. It paints a picture of how significant learning might be happening in very young children, aged 2-4, as they are engaged in a variety of activities including reading books, watching videos and visiting museums with their parents (Crowley, 2002). These findings suggest that even when individual experiences are seemingly insignificant, if learners continue to refine their understanding of a given area through participating in such activities over long periods of time, they will build expertise in the area beyond what is expected of them at their particular developmental level. This learning depends on parents helping their children notice critical features, concepts, and themes among their experiences over time.

This research has many implications for the role of teachers and facilitators in learning environments. One such role is to help learners make sense of their experiences and make connections between experiences through helping them to see the affordances and constraints of and similarities and differences between the artifacts they engage with within these experiences.

In KSI, Islands of Expertise greatly influences the roles facilitators play in helping learners to reason with artifacts and understand the importance of these artifacts in affording or constraining certain outcomes. In addition, it has made me focus on moment-to-moment interactions in the analysis of the learning in the KSI enactment presented here. In looking at the moment-by-moment interactions from an Islands of Expertise perspective, I try not to overlook the small steps that participants make in their understanding and how seemingly insignificant interactions can accumulate into significant learning for participants in KSI.

3.1.6 Communities of Practice, Cognitive Apprenticeship, and Communities of Learners

Over the past 20 years, research on professional apprenticeships has highlighted the roles of social situations and cultural environments play in influencing learning practices and not just content (Lave & Wenger, 1991; Wenger, 1998). These authors argue that knowledge and learning is situated in the resources, time, place, and culture and people of the community. As such culture and social interactions of participants in the community provide the context to encourage performance of the rituals and practices that help participants come to know in rich, messy environments.

Lave and Wenger (1991) articulate the richness and messiness of social situations that has focused on social situations as an infrastructure for learning. In particular they focus on the roles that the physical and social context of learning play in shaping what people know, how they know, and in what circumstances they are considered to know in external processes of learning. In this way, social situations provide a context for the development of skills and practices, and for understanding when such skills, tools, and artifacts are relevant, important, and useful. In practice, disciplinary and real-world authenticity of practices and culture is hard to emulate in designed learning environments because there are numerous layers of complexity in real cultures and communities that are hard to reproduce (Barab et al., 2004). However, this research suggests that each social situation or community has a culture that people tap into to understand what are valuable knowledge and skills in that community and how to use them to achieve the goals of the community.

Wenger (1998) further develops the importance of social situations and culture informing what and how people learn through conceptualizing this infrastructure for learning as residing in communities of practice and being driven by the values of the community and the values of the individuals in the community. So the infrastructure is a ***valued enterprise*** and the social interactions in pursuit of these enterprises that make individual and collective engagement meaningful and valued. Wenger suggests that active participation shapes not only what we do but also how we interpret what we do. From Wenger's perspective, it is the social aspects of our experience that make things valuable and meaningful. As such, Wenger suggests that the culture of valued enterprise, communal goals and practices for achieving the enterprise as a means for supporting learning within these communities.

Designers of learning-by-doing approaches have taken suggestions about how to promote learning from the ethnographic work on apprenticeship and culture presented in the work of Lave and Wenger. Here I highlight two approaches we drew upon in designing KSI, Cognitive Apprenticeship (Collins, Brown, & Newman, 1989) and Communities of Learners (Rogoff, 1994), as examples of the how the suggestions from this research have been implemented to foster learning in the classroom.

Cognitive Apprenticeship is a classroom approach to teaching students higher order reading, writing and mathematics skills (Collins, Brown, & Newman, 1989). Cognitive Apprenticeship is based on notions of traditional apprenticeship in the sense that the teacher plays a more active role in modeling the cognitive strategies that students need to perform expert tasks in the context of the tasks and situations that demand completion of the task. The key feature of the cognitive apprenticeship model is that the cognitive strategies used by experts are made visible by both the teacher and the students so that both have the opportunity to inspect and comment on them through think-aloud and read-aloud protocols.

In KSI, we drew upon the idea of supporting participants in reasoning scientifically by having the facilitator model her own scientific reasoning as she helps the participants solve problems. Thus, the facilitator engages in a think-aloud process so that participants can understand what she is doing and why and so that participants can see when scientific reason is use and how to use it. We have participants make their reasoning explicit when they make decisions about what ingredients they will use and why when they are perfecting their recipes. In particular, both the facilitator and the participants are required to show how they use evidence from the experiments they've run and previous experiences to make their choices.

Rogoff (1994) suggests a "community of learners" model based on the premise that learning occurs with others, with all participants playing active but often asymmetrical roles in socio-cultural activity (p. 209)." Participants in a Communities-of-learners learning environment work with adults to explore their ideas and construct artifacts to test and reflect upon their ideas. Communities of learners transform the learner-centered model from just a focus on learners and their needs to apprenticeship models where both the teacher and the learner are active but unequal in the roles that they play. Thus, both the facilitator and the participants can learn from one another.

In addition, the Communities-of-Learners model "goes beyond the idea of piecemeal incorporation of innovative techniques (e.g., modeling and activities that promote learning) into an otherwise inconsistent fabric of the [traditional] instructional model" (Rogoff, 1994, p.214). In order to avoid the simple "piecemeal" incorporation of suggestions from other successful approaches that lack context of applicability, Communities-of-Learners model focuses on the socially situated nature of learning and knowledge and makes suggestions about creating a learning culture. In this model, culture is defined/conceptualized as "a coherent system of practices integrated in a largely tacit underlying philosophy carried out in a community organized for children's education but serving many other functions as well for its members (p. 218)." In the particular example that Rogoff points out in one of the Communities-of-Learners learning environments, "children and adults collaborate in learning endeavors of interest to both the children and the adults, with adults being responsible for guiding the process and children learning to participate in the management of their own learning (p. 218)." Thus, culture is conceptualized as a philosophy for interactions between students and adults and how learning happens.

KSI takes into consideration both on the recommendation of the Communities-of-Learners model and the recommendations of LBD, to create a learning culture through rituals that become more tacit and easier to engage in over time. In addition, KSI considers the reciprocal nature of learning between participants and facilitators. Thus, both parties are there to learn from each other while perfecting the recipe.

3.1.7 Discussion

All of these approaches draw on theories of how learning happens to make suggestions of how to design activities, what resources to provide, and how facilitators can support participants in the learning process.

Constructionism makes suggestions about the roles constructing and designing artifacts plays in helping participants manipulate and internalize concepts and processes that are defined and constrained by the materials, tools, and resources participants interact with to create these artifacts. Likewise, Social Constructionist approaches makes suggestions about the role audiences play in providing a motivational medium for learning and engagement.

KB suggests making these ideas visible through written reflection and housing them in a central communal repository for ideas generated in the community is important for participants to learn from their own experience and those of others.

KIE suggests that activities and activity sequencing should be structured to help participants revisiting, connecting, clarifying, and improving their ideas and understanding over time so that new knowledge can be integrated into existing knowledge. In addition, KIE and Cognitive Apprenticeship suggest that the facilitator plays a big role in helping participant make thinking visible by modeling their own thinking.

Islands of Expertise expands on the role of the facilitator to include helping participants notice critical features of artifacts, reflect on concepts, and recognize themes among their experiences over time. In addition, Islands of Expertise also suggests that learning happens through small incremental interactions with artifacts and through conversations.

The Communities of Learners model agrees with this notion of how learning develops in suggesting that learning occurs through interactions with others around a shared goal.

LBD incorporates the suggestions of all of these approaches in the design of its approach. Thus, LBD makes specific suggestions about pulling together the design of activities around a central question; sequencing of activities to provide opportunities for participants to revisit, clarify, and revise their ideas, and share their ideas; creating social arrangements and rituals for groups to work on and share their ideas; and creating an overall culture that values idea-sharing and iteratively refining ideas and using evidence through oral, written, and design of artifacts. We have modeled KSI after LBD and these other learning-by-doing approaches to create an afterschool learning environment for middle school children to grapple with their ideas and explore science through their interest in cooking through creating a learning culture and environment specifically designed to support such learning and exploration.

In summary, using learning-by-doing learning environments as a context to engage participants cognitively requires a lot from participants and assumes that activities, resources, and facilitation are in place to support the engagement. As Knowledge Building suggests, epistemic agency of individuals and collective cognitive responsibility of groups is required for participants to gain understanding and to learn about concepts and topics. Unstated but assumed in all of these approaches is that the elements of these approaches will inspire participants to have this type of agency and to actively engage both physically and cognitively. Activities, resources, and facilitation only serve as guidelines for participants about the important types of cognitive engagement they should engage in and what to focus on. However, to realize the affordances of these approaches requires participants to physically engage enough in activities to care, to pay attention, to form and articulate their opinion or idea, to have expectations, to design artifacts or research the topic to explore their ideas, and to reflect on these experiences, to recognize when their expectations have or have not been met, and revise their understanding. These approaches ensure that participants have the opportunity to do such things but what does it take for participants to willingly and actively cognitively engage in taking up these opportunities? KB, KIE, and LBD suggest building a culture where participating in such ways is valued and rewarded, but is there something more fundamental going on in these learning cultures and environments that lead to participants being able to engage in these ways?

3.2 Practical and Theoretical Issues with Learning-by-Doing

3.2.1 Practical Issues with Learning by doing

In general, there is a lot of variability in what participants learn as they participate in learning-by-doing learning environments. In learning environments where participants are encouraged to develop design and construction projects based on their interest, what they learn is almost completely driven by their own interest and to some extent the direction suggested by a mentor. For example, learning in the Computer Clubhouse is learner-interest and activity driven, thus the scope of what participants learn is based on what they need to know to complete the project plus the nature of the guidance of the mentor. In learning-by-doing learning environments with more structure and scaffolding, what participants learn and the extent to which they learn it is governed by what participants focus their attention on and the activities they choose to engage in. However, to realize the affordances of activities and resources requires piquing and sustaining participants' interest, agency, and ensuring significant interactions with artifacts with a purpose.

3.2.2 Theoretical Issues with Learning by doing

I believe that in our excitement to make learning more authentic we have taken principles from situated theories of learning (e.g., Lave & Wenger, 1991 and Hutchins, 1995) about what promotes learning in everyday settings but we may have missed out on understanding the role that people play in taking up these affordances. Thus, I believe there is a gap between the intended goals of the designs we create and what actually happens when these learning environments/activities/programs are implemented.

There may be several reasons for this gap between what we design and what actually happens:

- There may be a mismatch in the goals of the design versus the goals of participants.

Wenger (1998) implies that such a one-to-one matching of intended goals of our design with the actual goals often may not be supported in reality. Thus, it is important to look at the actual ways that the fruits our designs are bearing. This requires us to look closer at our intended means for promoting engagement and learning and understand how these means work. In addition, he suggests that you may see the use of your tool and the results that you expect but the reason and motivation and appropriation of those tools are not motivated by your intended goals. Thus, this suggests that we may want to look more deeply at what is actually causing the engagement and learning that we designed for. Furthermore, this suggests that there may be another gap:

(2) There may also be a gap between the expected circumstances to reach the cognitive engagement goals intended by learning-by-doing design elements and the actual circumstances necessary for reaching those cognitive engagement goals.

By circumstances, I am implying two things: (1) the situational contexts that promote this learning (e.g., the interactions participants have with others and focal phenomena and the physical and social conditions that give rise to those interactions); and (2) the engagement required of the participants to take up the affordances in these situational contexts.

Thus, understanding how to bridge the gap between the expected circumstances for cognitive engagement and the actual circumstances necessary for cognitive engagement requires understanding more about the material and social interactions participants have in these learning environments and the influence they have on their cognitive engagement. In addition, it will require an understanding of how participants take up the affordances of these situational contexts and the physical and social conditions that lead participants to engage or disengage from activities.

In the same way that designers of consumer products and software interfaces consider placing buttons in certain places, and providing navigational aids to help people know where they are (Norman, 2002); educational designers, researchers and educators need to not just integrate affordances for learning into activities and provide resources to support this or assume that, for example, simply putting participants in small groups will result in cognitive engagement. Rather we need to seriously consider the ways we organize, arrange and configure the physical space and people and artifacts within that space to make suggestions about what to pay attention to even when participants are engaged in other activities. In this way, we are configuring learning environments as if they were web pages with advertisements to other related and interesting things that participants can pay attention to. However, instead of these infrastructural advertisements being distractions to learning, we need them to be embedded prompts to attend to things that are important to notice, to reflect upon, and to discuss. But that first requires understanding when, where, and why a participant may want to look at these prompts and engage in them.

3.3 Shifting the Focus from Evaluating Effectiveness of Designs to Looking at Participants' Experiences and Interactions within these Designs

In Part II of this dissertation, I begin to answer some of the questions that I raised in this chapter and to explore the two gaps I propose exist between the design goals of learning-by-doing learning environments and the realization of these goals. To do this, I shift my focus away from the temptation to evaluate leafarning from the perspective of whether or not the learning-by-doing learning environment is achieving its goals when implemented, and I shift my focus to exploring participants' experiences in a learning-by-doing learning environment, KSI. In this exploration, I look at the ways that participants engage their senses, interact socially, and engage cognitively. In addition, I look at the focus of participants' attention and physical and cognitive activity to understand if they are engaging for the purpose of learning or for some other purposes they may have. Last, I look at the physical and social configurations in which they engage and what promotes or inhibits their engagement.

I am not the first researcher to shift focus onto participants' experiences, or to do so from a situated perspective. Joanne Lobato, Randi A. Engle, and James Greeno, among others, have focused their attention on studying transfer (and learning) from a situated and interactional perspective. Their research suggests that by shifting our focus on the mechanisms of transfer, we will better understand how transfer (and learning) happens. I refer to this work here because it suggests the scope and granularity in which I seek to analyze participants' engagement in learning-by-doing learning environments to gain a better understanding of what influences and inhibits learning in these environments. In particular, their research suggests that this level of analysis can reveal interactional mechanisms of transfer (and learning) that help us understand what leads to transfer.

Lobato (2006) suggests taking an "actor-oriented approach" in the exploration of transfer from a situative perspective, to reveal idiosyncratic ways in which learners generalize their learning experiences. She also suggests that by shifting our perspective onto individual participants, we are able to look at the aspects in the learning environment that focus participants' attention and help them to notice important features that are necessary for both learning and transferring knowledge. For example, Lobato, Ellis, Munoz (2003) propose the concept of "focusing phenomena" as a mechanism of transfer. They report that focusing phenomena are features of the classroom environment that regularly direct students' attention toward certain (mathematical) properties or patterns when a variety of features compete for students' attention. In addition, focusing phenomena link features of instructional environments with the particular ways in which individuals generalize their learning experiences. Lobato (2004 & 2005) suggests that focusing phenomena emerge differently in different instructional environments. Lobato (2006) demonstrates that “differences in the nature of students' generalizations of their learning experiences are related to differences in features of the classroom environment that regularly direct students' attention toward certain mathematical properties when a variety of features compete for students' attention” (p. 110).

Furthermore, Lobato (2006) suggests that as the research on these new transfer processes develop, we as a community can begin to challenge widespread beliefs about how transferable knowledge can be supported in learning environments. For example, she suggests that her work on focusing phenomena challenges the widespread belief that “knowledge that is taught in one context is less likely to support flexible transfer than knowledge that is taught in multiple contexts (Bransford et a., 2000 p. 78).” (quoted by Lobato, 2006, p. 444). In particular, she reports that her findings on focusing phenomena suggest that rather than the widespread belief that it is the number of contextual situations that is crucial to transfer, the particular disciplinary regularities and properties to which students’ attention is drawn and for which they notice are really the crucial elements that support transfer. Such an assertion is consistent with my claim that by focusing on participants’ engagement in learning-by-doing learning environments we can uncover underlying mechanisms that can help us understand better how the affordances of these environments are taken up by participants.

Similarly, Engle (2011) suggests that “many of the newly-designed learning environments” require “students’ deep involvement in and progress on concepts and/or practices characteristic of the discipline they were learning about,” which she characterizes as productive disciplinary engagement (Engle, 2011, p.5, Engle and Conant, 2002), and that such engagement requires something more of participants than learning approaches based on traditional cognitive theories of learning. Engle (2006) suggests that a flaw in traditional design and evaluation of learning environments is the assumption that participants will use what they learn in the future and at the times that we expect (p. 456). In particular, she suggests that, "purely content-oriented explanations of transfer make one crucially flawed assumption: If learners have the right kind of knowledge at hand and know that it is applicable in a particular context, then they are going to use it. In contrast, I argue that transfer involves not just knowing but doing, and that doing inherently involves an exercise of human agency. Thus, if transfer is going to happen, I argue, it is necessary that learners choose to use what they have learned, although there is certainly no requirement that such choices be made consciously" (p. 455).

Furthermore, Engle (2006) suggests that participants' learning trajectories through learning environments are governed by the extent to which participants are actively involved in activities. Her research shows that participants who are more actively involved in "constructing the content increased their involvement over time, and showed evidence of being capable of independent use of that knowledge, one might expect—all other things being equal—that this learner would be more likely to generatively use that content when appropriate situations present themselves. (p. 455)"

Thus, taking this perspective, Engle's work has identified four explanatory factors that are useful for characterizing cases of productive disciplinary engagement: (1) problematizing, (2) authority, (3) accountability, and (4) resources. For the purposes of the argument I set out in this thesis, problematizing and resources are covered in the things we already take into consideration when designing learning environments, and authority and accountability focus on the roles that participants play in these learning environments. In particular, Engle's analyses of the importance of framing participation for transfer suggests different forms of participant authority are mechanisms for transfer. For example, when participants are positioned as authorities in content and in means of becoming an authority, they develop agency to act in new situations as an authority and to use their understanding across contexts.

This body of research suggests that taking a situated and distributed cognitive perspective is productive for being able to understand the ways that participants engagement in learning-by-doing learning environments promote or inhibit their cognitive engagement. With the analyses that I present in this thesis, I contribute to this body of research through identifying additional hypotheses about mechanisms that promote or inhibit cognitive engagement in learning-by-design learning environments and the circumstances in which these mechanisms function.

Just as I am not the first to look for underlying mechanisms that promote or inhibit cognitive engagement, I am not the first researcher to look at the roles of physical layout, artifacts, and social configurations on learning. Roth et al. (1999) looked at how different artifacts, social configurations, and physical arrangements create different types of interactional spaces that affect the level of participant discursive engagement and subsequent cognitive engagement and learning. Interactional spaces are focal areas of participant interaction that are codetermined by focal artifacts and task structure. These interactional spaces determine the physical arrangement of participants and what is available for them to see and hear about the content and thus, the ways that they engage in discussions about the task and the focal artifacts. His findings suggest that participants' placement in these interactional spaces change the nature of discourse and the focus of the conversations and the extent to which they engage. His work suggests that looking at the physical, material, and social configurations of learning-by-doing learning environment can contribute to understanding the circumstance and factors that influence when and how participants cognitively engage. The analyses presented in this dissertation extend his research by providing more nuanced descriptions of how these configurations impact not just opportunities for discursive engagement but also sensory, social, and cognitive engagement.

3.4 Analytic Focus for Analyses Presented in this Dissertation

As I briefly mentioned earlier, the work of Lobato, Engle, Greeno, and Roth builds on the ethnographic research of Edwin Hutchins, Jean Lave, and Etienne Wenger, which is foundational to Situated and Distributed Cognition. Here I discuss Hutchins, Lave, and Wenger's work explicitly as I believe the rich descriptions in this research also point to the role that interactions and experiences that are needed for learning to develop in context. I do so for the expressed purpose of highlighting the analytic focus of the work I present in Part II of this thesis.

In particular, Hutchins (1995) suggests that cognition is distributed between the individual, artifacts, and other people. In this articulation of cognition, social and material interactions and experiences play a key role in how people come to know and learn. For example, interactions with maps and telescopes to locate sites allow quartermasters to communicate with one another to figure out the location of the ship and the direction the ship is headed. Such interactions allow less experienced quartermasters to learn about how to use tools to calculate the ship's location. Lave and Wenger (1991) suggest that social interactions are key in defining what people pay attention to and the value they place on their experiences. These interactions include watching, listening, and observing others while doing their own job.

This work was been a great source of motivation for me as I've pursued an exploration of the roles that social and material interactions play in promoting engagement and cognitive engagement. It played a central role in how I look at the ways that middle school participants are actually engaging in the activities we've designed, interact with the resources we've provided, and what influences or prohibits the ways that they cognitively engage.

I summarize the goal of this exploration in my first research question aimed at looking at "What are the types of interactions and experiences that promote and/or inhibit learning and engagement in learning-by-doing learning environments?" I believe the findings from this exploration will highlight the underlying mechanisms that enable the realization of the intended goals of our designs. My findings from this dissertation work suggest that sensory and social engagement are important foundational mechanisms that enable cognitive engagement during participation in learning-by-doing activities. Chapters 5 & 6 explore sensory, social, and cognitive engagement more deeply.

In answering research question #2: What are the types of configurations that promote and/or inhibit learning and engagement in learning-by-doing learning environments?, I turn to Hutchins as an analytic lens. Hutchins (1995) conceptualizes the infrastructure for learning as residing in the socio-material-technical system of the learning environment for which people, materials, tools, and technology are interacting to solve problems and perform tasks. For example, Hutchins' (1995) analysis of quartermasters on the bridge of a ship highlights explicitly the roles that material, social, and physical layout configurations of a space can influence what different quartermasters were able to see and not see and how that influenced how they learned to do higher-ranking jobs on the ship. In particular, Hutchins suggests that the visual and auditory "horizon of observation" created by centralized social and physical configurations in the bridge of the ship allow the quartermasters to watch and overhear the interactions of others working in the bridge to gain an understanding of how to navigate the ship.

Hutchins (1995) defines the horizon of observation as the boundaries on a socio-material cognitive system as defined by the outer boundary of the portion of the task that can be heard or seen by each member (Hutchins, 1995, p. 268). The horizon of observation is defined by (1) the lines of communication and (2) the limits on each participants' observation of the activities of others. Thus, the spatial layout affords the physical proximity to hear or overhear conversations of the adjacent group and to visually observe and inspect the coordination of the social and material aspects of the task and the designed learning environment.

In addition, Lave and Wenger's (1991) descriptions of the Vai tailors and butchers suggest that physical, material and social configurations can influence or inhibit the extent to which participants are able to watch, listen, and observe others while doing their own job and the role this plays in their overall understanding of how work is performed in the community and how participants learn to play other roles in the community. For example, along with the culture of tailoring being that each person can do everyone else's job, Lave and Wenger (1991)'s account highlights that the tailors are able to see each other performing these various roles and duties such that when it is their turn to perform those duties, they are able to do so much easier than if they had not had the opportunity to watch others perform those skills. However, their research also shows what happens when such affordances are not available. In particular, the impact of the lack of physical and social configurations is seen in Lave & Wenger (1991)'s analysis of the butchers, who worked with little visual and auditory access to what other butchers were doing, struggled to understand the impact of their work on other butchers and the processes that meat went through before it was read for purchasing.

These examples suggest that participants' cognitive engagement is contextualized in the spatial and temporal configurations and coordination of people and materials in the learning environment. In addition, they imply that there is a need to look at the influence of physical layout, social and material configurations on engagement and learning. Hutchins's (1995) analyses suggest that shifting the unit of analysis away from how social interactions and artifacts help form internal representation to exploring the experiences of social participation and material coordination in learning environments can provide a productive lens on understanding the cognitive engagement of participants. So I use physical, social, and material configurations as units of analysis to understand the influences on participants engagement and cognitive engagement in these my analysis.

3.5 Chapter Summary

This literature review highlighted the intended engagement and cognitive goals of learning-by-design learning environments and the ways that we have tried to support them through the design of activities, provision of resources, and the adapting of facilitation. I raised issues about (1) the focus of research in learning-by-doing learning environments and (2) the unit of analysis of participant engagement in these learning environments. Addressing these issues provides scope for the research presented here where I look at participants' engagement in learning-by-doing learning environments, interactional mechanisms that lead to engagement and learning, and the circumstances that lead participants to take up the intended affordances of these learning environments. In particular, I look at the different aspects of participants' sensory, social, and cognitive engagement to understand the processes and mechanisms that are enabling participants to learn in learning-by-doing learning environments.

In addition, this chapter has highlighted the theoretical foundations behind the design goals of the Kitchen Science Investigators (KSI) program. In particular, it highlights the theoretical and empirical basis for our intended engagement and cognitive engagement goals upon which we designed the activities, facilitation, and resources we designed in KSI. Since KSI is a Design-based research project it also shows how we use these theoretical and empirical basis to design. It then shows that a DBR project such as KSI offers insight into other units of analysis for supporting engagement and learning and a basis for moving from practice to theory. In this chapter I have also outlined my analytic focus for the analyses presented in this dissertation.

Now as we move into Part II of this dissertation, I will discuss the findings of this dissertation on the aspects of sensory, social, and cognitive engagement that fosters learning and the physical layouts and social and material configurations that afford this type of engagement.

CHAPTER 4

METHODS

The primary focus of this dissertation is to understand the ways that participants engage physically and cognitively in learning-by-doing learning environments and the circumstances in which participants take up the affordances of these learning environments. To this end, the research presented here is guided by two research questions:

RQ 1. What are the types of interactions and experiences that promote and/or inhibit learning and engagement in learning-by-doing learning environments?

RQ 2. What are the types of configurations that promote and/or inhibit learning and engagement in learning-by-doing learning environments?

This chapter describes the methods I use to answer these research questions. In particular, it provides a detailed description of the analytic and organizational steps I take to create the stories of participant learning and engagement in KSI.

4.1 Overview

Since this is an under-researched area of educational, cognitive, and learning research, it is necessary to take an exploratory approach to understand how "doing" actually provides opportunities for physical and cognitive engagement. Thus, I have chosen to employ qualitative research techniques and approaches to explore this research space. In particular, I used a technique of forward and backward mapping from key events or anchor points (Putney et al, 1999) to construct rich descriptions/learning stories of what and how participants learned science content and skills in KSI[1]. These learning stories allowed me to identify episodes that played key roles in engaging participants physically and cognitively, and that later promoted participants' science content learning.

Then I used grounded theory (Strauss & Corbin, 1998) to analyze the learning stories and constructed a descriptive list of patterns in participant interactions and experiences that promoted and/or inhibited physical and cognitive engagement and learning. In addition, I identified a descriptive list of patterns in physical layout, social, and material configurations that afforded these interactions and experiences. This allowed me to empirically identify interactional and contextual affordances that facilitated and/or hindered processes of physical and cognitive engagement in KSI, and to explore how these affordances arose and how these opportunities and affordances were created and/or taken up by participants.

Lastly, using grounded theory, I constructed a substantive theory[2], a model that highlights the relationships between the physical layout, social configurations, and material configurations of the learning environment and participant interactions and experiences that promote physical and cognitive engagements necessary for learning in KSI.

4.2 Context of Research Study

Since the KSI research project was run as a design-based research study, we collected data over several enactments of the program. During and between each enactment, aspects of the learning environment and resources were changed in hopes of improving learning. I have selected two study enactments to investigate to address my research questions. Enactment 1 at The McDowell School[3] was carried out over two 10-week periods held during Spring 2005 and Spring 2006. Enactment 2 at the New Hope Middle School was carried out in a 20-week study during academic year 2007/2008. In both studies, the program was offered once weekly for 1 ½ hour sessions (with the exception of school holidays). Activity facilitation was provided by two Ph.D. student researchers, Tamara Clegg and myself, during both enactments.

4.2.1 Enactment Details

4.2.1.1 Enactment 1: The McDowell School[4]

Enactment 1 was held at the McDowell School, an elite suburban private K-12 school. The participants in Enactment 1a (Spring 2005) were fifth graders. There were 16 total participants in the study: 8 girls and 8 boys. The racial composition of our participants reflected the school's population. Fourteen participants were white and two were black, one female and one male. The participants were recruited by their science teacher through brochures advertising the program. Thus, participants voluntarily elected to participate in the program as an after-school science club. The participants in Enactment 1b (Spring 2006) were 17 sixth graders, 75% of whom were in Enactment 1a. In Enactment 1b, we lost three girls from the previous enactment to other extracurricular activities, and four boys replaced them.

4.2.1.2 Enactment 2: New Hope Middle School

The participants in Enactment 2 (2007-2008 academic year) were in sixth through eighth grades in a middle-class suburban public middle school, New Hope Middle

School. There were a total of 26 participants enrolled in the program. Since participation was voluntary, the weekly participation varied, but the average was approximately 16 participants per week. The majority of those participants were regular attendees. All the participants in this study were females because KSI was offered as part of a girls-only technology program offered by the local YWCA[5]. The all black racial composition of our participants reflected the school's 99% African American population. Each of these participants volunteered to participate in the program.

4.2.1.3 Pragmatic Changes between Enactments

From a design-based research perspective, I selected these two enactments to show the progressive refinement of the KSI program. Enactment #1 suggested the need for the implementation of a number of changes to improve the overall learning in the program; Enactment #2 allowed us to see the results of those changes. From the perspective of suitability to answer my research questions, these two enactments were selected because they were run in the same format (with the exception of the changes we made to the curriculum and resources).

Based on analysis of the first enactment, we saw a need to make several pragmatic changes in the design of KSI to improve the quality of the program and learning in subsequent enactments: we (1) increased availability of resources, (2) created software for creating stories, (3) created software for creating explanations, (4) changed the cooking activities to better match participants' cooking interests, and (5) increased facilitators' knowledge of the science.

During Enactment 1, there was contention for commonly used ingredients (e.g., sugar and salt), and we noticed that participants seemed to get distracted from the cooking task when they went in search of an ingredient for which we only had a single container. These distractions sometimes led to groups finishing at different times, which hampered the timing of other activities. Therefore, we made more resources available to individual groups to alleviate the contention and to keep participants focused and on task.

Reflection is a major part of the way the KSI program helps participants make the connection between the cooking and the science. Participants in Enactment 1 began spontaneously writing stories about their experiences when asked to record their cooking observations (Gardner, Clegg, Williams, & Kolodner, 2006). Prior to students writing stories, we had a difficult time getting the students to reflect. However, while writing these stories, participants spent a good deal of time working with their group members and discussing their activities and observations with one another without being prompted. Therefore, we designed the Story tool, which is a software-based story-writing tool, to give participants who enjoyed writing an opportunity to share their experiences with others (see Chapter 2, Figure 2.4 for a screenshot of this tool). In the process, we hoped it would encourage participants to reflect on, and talk about, their experiences with one another in a way that was personally meaningful to them (Gardner & Kolodner, 2007). We based the need for the story tool on the natural inclination of participants in previous implementations to create stories when they reflected on their experiences in KSI (Gardner et al., 2006). In enactments following Enactment 1, we found that this tool helped participants to write stories about the purpose and value of their KSI experiences (Gardner & Kolodner, 2007). The Story Tool was used in Enactment 2.

During the first enactment, we noticed that participants were very engaged in cooking, and at times it was hard to engage them in the scientific aspects of what they were doing. As we had seen that participants liked sharing their discoveries with others, we designed the Explanation tool, a software-based tool that scaffolded the creation of scientific explanations. In an enactment between Enactments 1 and 2, Gardner and Kolodner (2007) found that the explanation tool encouraged participants to focus specifically on the science they were learning and not just on their cooking experiences. Thus, we continued using the explanation tool in Enactment 2.

The participants in the first enactment were excited to prepare any recipe we gave them, but we knew that might not be the case with all middle school children who would participate in the program. Thus, we knew we needed to tailor the recipes to the interests of each group of participants with whom we worked. We also knew that participants' engagement and subsequent learning would be tied to experiences they found personally meaningful (Resnick, Bruckman, & Martin, 1996). Therefore, we refined the facilitation to incorporate participants' cooking interests (e.g., recipes for homemade tortillas and cheese sauce) to increase engagement and to make the science learning personally meaningful.

Finally, during Enactment 1's 10-week unit on Thickeners, we saw that our design included too little science content. In particular, it lacked depth of mechanistic causes for thickening. This made it difficult for participants to relate the science to their cooking experiences. We found that this confused the participants, and as a result, they focused more of their attention on the cooking than the science. Therefore, we refined the science content to include more detailed explanations of how the structure of starches causes thickening. This refinement also satisfied a need to include more depth of science content for participants who desired it.

4.2.1.4 Similarities and Differences between Enactments

The enactments were equivalent in their amount of participation time, overall activity sequencing, learning content, and lead facilitators. However, there was naturally-occurring variety. This variety would confound comparison of the two enactments. However, the combination of the two enactments offers a diversity of interactions and contexts that lend themselves well to identification of the development of participants' learning and the factors that facilitated or inhibited that learning. These differences include (1) the participants' background and experiences including their familiarity with inquiry, (2) the way the activity sequence was facilitated, (3) the interests of the participants, (4) the science knowledge and capabilities of the participants, (5) the socio-economic status (SES) of the schools, (6) the location of the learning environment within the school building, (7) the spatial arrangement of the learning environment, (8) the software functionality, and (9) the cooking resources. Below are two charts that summarize the two enactments. Table 4.2 summarizes details about similarities and differences in the participants, and Table 4.3 summarizes details about similarities and differences in the program implementations.

Table 4.1 Summary of Participants in Each Enactment

Enactment Participant Information			
	Enactment 1: The McDowell School		**Enactment 2: New Hope Middle School**
Components	**Spring 2005**	**Spring 2006**	**2007-2008 Academic Year**
Location	Suburban K – 12 Private School		Suburban Public Middle School
Participant Recruitment	Voluntary participation in an afterschool science club	Voluntary participation in KSI. KSI offered as an afterschool program	Voluntary participant in a YWCA organized afterschool program
Grade	5th graders	6th graders	6-8th grade
Participant Familiarity with each other	Same science teacher, possibly in different class periods; Possibly in the same school since kindergarten		5 different teachers (8th grader two different teachers, possibly different class period; 6th grader two different teachers, possibly different class periods; 7th grader different teacher)
Participant Familiarity with Inquiry	all classes at the school were inquiry-based		Inquiry-based teaching is taught only in science high-achievement classes.
Pacing of Participants classes	Accelerated-pace		6th grade mixed pace 7th grade (no information available) 8th grade Accelerated-pace

Table 4.2 Summary of Program Details for Each Enactment (Part A)

<table>
<tr><th colspan="6">Enactment Program Details</th></tr>
<tr><td></td><td></td><td colspan="2"><u>Enactment 1: The McDowell School</u></td><td colspan="2"><u>Enactment 2: New Hope Middle School</u></td></tr>
<tr><td></td><td><u>Components</u></td><td><u>Spring 2005</u></td><td><u>Spring 2006</u></td><td colspan="2"><u>Fall 2007 – Spring 2008</u></td></tr>
<tr><td rowspan="2">Activities</td><td>Sessions</td><td colspan="4">10 sessions/ 1.5 hrs</td></tr>
<tr><td>Content</td><td>Leaveners</td><td>Thickeners</td><td>Leaveners</td><td>Thickeners</td></tr>
<tr><td rowspan="4">Technology Usage</td><td>Software usage</td><td>Last 3 sessions</td><td>All 10 sessions</td><td>Last 4 sessions</td><td>All 10 sessions</td></tr>
<tr><td>Recipes & recording observations</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Stories & explanatoids</td><td></td><td></td><td>X</td><td>X</td></tr>
<tr><td>Planning experiments</td><td>X</td><td></td><td></td><td>X</td></tr>
<tr><td rowspan="5">Social Support</td><td>Facilitators</td><td colspan="4">Tammy & Christina (Ph.D. project leads)</td></tr>
<tr><td>Additional help</td><td>2 people</td><td>2 people</td><td colspan="2">3-4 people</td></tr>
<tr><td>Site Coordinator</td><td>5th grade science teacher</td><td>5th grade science teacher</td><td colspan="2">YWCA staff person (rotated through 4 different people)</td></tr>
<tr><td>Principal Investigator</td><td>Occasionally</td><td>Occasionally</td><td colspan="2">Regularly</td></tr>
<tr><td>Group Size</td><td colspan="2">4 participants per group</td><td colspan="2">3-6 participants per group</td></tr>
</table>

Table 4.2 (Continued)

Physical Environ-ment	*Location of Learning Environment in the school*	All-purpose atrium of the school outside of the industrial kitchen	Home Economic room (Kitchen and Classroom)
	Physical Spatial Arrangement of the workspace	Workspace constrained and shared – 2 groups per table, 2 tables 6-8 feet apart	More Dedicated workspaces – 2 groups had their own kitchenette, 2 groups shared a table and worked closer together
	Cooking Utensils and Equipment	Small-group dedicated	Small-group dedicated
	Ingredients	Shared across groups	Small-group dedicated
Partic-ipation	*Weekly Attendance*	14-16 participants	Average 16 participants
	Total # of participants	16- 17 participants	26 participants
	Weekly Variability	very little variability	high variability

4.3 Data Collection

To answer my research questions, I used several types of data that we have collected from the two enactments of the KSI program: (1) video recordings of the activities in the KSI learning environment; (2) facilitator/researchers' reflective field notes from each session; (3) participant-created physical and digital artifacts; (4) video-taped interviews with participants, parents, and teachers; and (5) the goals and objectives of the designed activities. Table 4.3 summarizes the data collected in each enactment.

Table 4.3 Data Collected from Each Enactment

Data Source	**Enactment 1**	**Enactment 2**
Video of Participants during activities	5 cameras, 1.5 hrs video/camera, 1 camera/group, and 1 global camera	4 cameras, 1.5 hrs video/camera, 1 camera/group, no global camera
Participant created Physical & Digital Artifacts	observations, recipes and observations created in the software, digital photos	observations; recipes and observations created in the software, digital photos, in addition, experiment plans, stories, and explanations created in the software
Field notes	Ethnographic field notes, reflective field notes from two facilitators	No ethnographic field notes, Reflective field notes from two facilitators
Video-taped Interviews	Individuals and group interviews	Interview with selected participants, their parents, and their teachers
Goals and Objectives of the designed activities	Activity sequencing, materials, activity directions and goals, science content memos	Activity sequencing, materials, activity directions and goals, science content memos, and facilitation suggestions

4.3.1 Video Recordings of Participants during Activities

Using four to five video cameras, we collected 270 hours of video over forty 1.5 hour sessions captured during 10 – 20 weeks of participants' engagement in the KSI program. The video recordings captured the on-going activity within the KSI program. These recordings captured both the global interactions in the environment and the intimate interactions of the children and facilitators as they participated in the whole-group conversations, small-group cooking activities, and used the computer software designed by the researchers for this particular environment.

4.3.1.1 Small-group Video Recordings

We used four cameras in each enactment to capture the small group activities. Each of the four cameras was focused on one of the four small-groups, allowing us to track participants in each small group throughout their participation in the program. The video cameras were positioned to record the visual and the audio of each group, as well as the social and physical interactions around the workspace. Thus, facial gestures, hand movement, artifact placement, interaction, and conversations were captured.

4.3.1.2 Whole-group Video Recordings

During whole-group activities, the four cameras were re-focused onto the whole group and captured different angles of the activity (e.g., participants and facilitators faces and upper bodies, artifacts on the table, and visual content they were attending to). Since participants were seated in a circle or semi-circle around a table for these activities, some recordings capture faces of a few participants while also capturing the backs of other participants. During Enactment 1, we used a fifth camera to capture the global interactions (e.g., the flow of participants around the room and some areas not covered by the 4 small-group dedicated cameras) during both small and whole-group activities.

This video data allowed me to study how learning developed over time through looking at participants' spoken words, interactions, and the contexts these interactions were grounded in over multiple sessions/weeks. In addition, I was able to understand how these interactions and contexts changed over time as participants' learning needs evolved. I used episodes from this corpus of video to construct learning stories of two groups of participants and to gain a better understanding of the patterns in participants' interactions and experiences and the configurations and situations that gave rise to them.

4.3.2 Physical and Digital Artifacts

To complement the video recordings and transcripts of participants' interactions, we collected the physical and digital artifacts that participants interacted with. In particular, we collected the papers on which participants wrote and the digital artifacts they created in the software before, during, and after cooking and science activities. For example, participants were given paper or software that allowed them to plan their experiments prior to cooking, record their observations while cooking, and write explanations and stories after they finished cooking. Sometimes the participants themselves created these artifacts. Other times they were collaboratively created by the participants and the facilitator and may have been recorded by the facilitators. Often in cases where the artifacts were written by the facilitators, the facilitator verbally and textually summarized the words of the participants and asked the participants to confirm the correctness of what was written. These written artifacts identify aspects of the activities and science learning that participants thought were significant. I used these artifacts to identify various stages of participants' conceptual understanding of the science they learned in the program and as a measure of cognitive engagement.

In addition, we collected digital pictures of perishable food artifacts participants created throughout the program. These pictures document the objects of participants' verbalizations and written observations.

4.3.3 Field notes

We also collected two types of field notes for this project. Since the researchers (Tamara Clegg and I) acted as participant observers through our roles as program facilitators, we recorded reflective field notes within 24 hours of participation in the program during both enactments. These field notes included general narratives of the activities done in each session, as well as the words of participants, their parents, their teachers, and other researchers when remembered. In addition, these records have reflections about phenomena of research interest and pragmatic issues related to supporting the learning.

The second type of field notes was only collected during Enactment 1. These field notes were created while two Masters students doing ethnography projects observed the participants in the learning environment. They focused on learning and pragmatic and technical issues related to supporting learning in KSI.

Both types of field notes provided additional context for the activities and interactions in the learning environment beyond what video could provide. The information in each was gained through informal conversations with participants, parents and teachers, as well as through observations. Some reflections included the personal attitudes, and biases of a researcher. I used these records to identify potential learning stories, related episodes of interest in the video corpus, and alternate hypotheses for the occurrence of phenomena.

4.3.4 Video-taped Interviews

During both enactments, we conducted several types of interviews. After the completion of each 10-week session during Enactment 1, we conducted individual and group interviews with the participants. The focus of the interviews was on understanding what participants learned in the program, the participants' understanding of the software, and other information we could use to improve the program. These interviews were performed by Tamara Clegg, Oriana Williams (a masters student), and myself. During Enactment 2, Tamara Clegg conducted one to three interviews with 6-8 participants, 2 interviews with each of those participants' parents (i.e., mothers), and 2 interviews with each of the participants' science teachers. Data from these interviews identifies specific content that participants learned and found personally meaningful from participating in the KSI program. I used these interviews to identify potential learning stories and to identify related episodes of interest in the video corpus with respect to episodes in which participants were cognitively engaged, or where they felt their physical engagement was meaningful.

4.3.5 Goals and Objectives of the designed activities

Lastly, we have written documentation of the goals and objectives of the designed activities and the rationale behind the changes we made along the way. This data was useful in helping me to understand the evolving design and implementation of the program and the learning environment. I used these records to identify content relevant sessions that may lead to identification of episodes of interest for developing the learning stories.

4.4 Data Analysis

The overall focus of the analysis was to understand the ways that "doing" actually provided opportunities for physical and cognitive engagement that are intended by learning-by-doing learning environments. In particular, I analyzed data from two enactments of the KSI program to gain an understanding of how participants learned science in the KSI environment. I worked in five phases to conduct the data analysis. The first four phases focus on understanding what KSI participants learned after 10-20 weeks of participation in the program and how that learning developed. The fifth phase focuses on why the learning developed in the way it happened. For this last phase, I specifically focused on how social, material, and technical interactions facilitated or inhibited physical and cognitive engagement. Also considered were the roles that physical layout, and social and material configurations of the learning environment played in fostering this engagement.

In Phases 1-4, I focused on identifying the content or skills that participants learned by the end of participating in the program. I also identified the relevant learning episodes to construct a temporal sequence of how the learning developed. I used a technique of forward and backward mapping from key events or anchor points (Putney et al, 1999) to construct learning stories from the available data.

In Phase 1, I identified science content and skills participants learned by the end of the KSI program. In Phase 2, I identified what episodes (events in time) may have led to that learning by tracing back through the data to identify a developmental path. I then identified artifacts associated with the learning and video episodes, which helped to describe how the learning and skills developed. Through this process, I assembled a high-level timeline that identified how these records were ordered and the cognitive engagement they suggested. In Phase 3, I identified what happened in those episodes by transcribing the identified video episodes of the learning story. In Phase 4, I identified why the learning developed the way it did and what afforded it happening. I also identified the specific path by which the learning developed through connecting the relevant episodes, interviews, and participant-created artifacts together to construct a temporal story of how the learning developed. I repeated Phases 1-4 to create at total of 2 case studies.

The fifth analysis phase focused on why the learning developed in the way it happened on the interactional and contextual level. This phase focused on analyzing these stories by using grounded theory to identify contextual and interactional affordances for learning, the process by which these affordances promote or hinder the development of learning, physical and cognitive engagement. The overarching goal of this phase of analysis was to use grounded theory to develop a substantive theory of how learning develops in an environment where learning is not the primary focus of participants. I did this through using the grounded theory process to first develop a descriptive list of participant interactions and experiences that may have influenced or inhibited physical and cognitive engagement. Then I developed a descriptive list of physical layouts, social configurations, and material configurations that may have influenced and/or inhibited physical and cognitive engagement.

4.4.1 Phase 1: Identification of science content and skills learned in KSI

Phase 1 focused on understanding what KSI participants learned after 10-20 weeks of participation in the program by identifying *what* science content and skills participants learned or developed in the KSI program. To identify this learning, I reviewed participant created artifacts, interview transcripts, and field notes from interviews with participants, their teachers, and their parents. I have noticed several types of learning that developed: (1) Cooking Skill(s), (2) Cooking Content, (3) Science Skills, and (4) Science Content. Table 4.2 illustrates examples of types of learning that developed over 10-20 weeks of participation in the KSI program.

Table 4.4 Examples of Learning

Types of Learning	**Definition**	**Examples**	**Source**
Cooking Skills	Showed evidence of developing or refining cooking related skills in KSI	Measuring Accurately	Interviews
Cooking Content	Rules of thumb and substitutions with regard to using particular ingredients to achieve a desired result	"Make a thin crust pizza by adding half the yeast, and sugar" "um, we um, we are changing, instead of yeast, water, and sugar, we're going to use baking soda and baking powder as a substitute for them"	Artifacts, Interview Transcripts and field notes, video transcripts
Science Skills	Showed evidence of developing or refining science related skills in KSI	Measuring Accurately, Making Observations, Making Hypotheses	Interview Transcripts and field notes
Science Content	Showed evidence of understanding how a particular ingredient worked: (a) written (b) Reported (c) demonstrated application	(a) "yeast eats sugar and … it reproduces! And… releases CO_2" (b) MK reported in an interview that she knew about yeast from science class as a fungus but did not know that or how it made things rise. The yeast-air balloon experiment helped her with this. (c) Teaching others about how to use cornstarch and flour	Artifacts, Interview Transcripts and field notes

4.4.2 Phase 2: Identify pieces of the learning story and associated artifacts

Phase 2 focused on identifying what led to the learning and identifying how the pieces of the learning story were ordered. I started by identifying episodes related to the learning, beginning with the learning instances identified in Phase 1. I found the pieces of the learning story by reviewing the video content logs, field notes, interviews, and participant artifacts. I defined episodes as small segments of video 5-20 minutes in length that feature interactions, conversations, and activities that were central to the learning or usage of particular science content and skills.

Next, I identified all of the artifacts associated with each episode. To identify activities/episodes that were associated with the identified learning in Enactment 1, I used the Activity Goals & Objectives and Field notes. To analyze Enactment 2, where a sufficient artifact trail did not exist, I relied primarily on using the activity goals and objectives and the field notes to identify relevant episodes. Throughout this process, I created a timeline of the episodes and the artifacts associated with those episodes. This allowed me to pre-screen the data for learning stories and helped to establish patterns of interactions and experiences that may have influenced or inhibited learning across the program. Thus, this process generated a list of questions about how and what experiences led to this learning, which helped me to identify additional episodes for investigation and comparison.

4.4.3 Phase 3: Transcription and analysis of the pieces

Phase 3 focused on transcription and analysis of the identified episodes to determine what happened in the episodes that may have influenced the learning. I started transcribing the data from the video episodes closest to the end of the program and worked my way backward to the beginning of the program using the timeline as anchor points. This was an adaptation of the technique of forward and backward mapping from key events or anchor points presented by Putney et al (1999). This process provided assistance in identifying a plausible learning path and relationships between participant interactions and experiences and the subsequent learning they afforded or inhibited.

In transcribing and analyzing the data, I identified interactions, actions, and configurations that may have influenced and inhibited participant physical and cognitive engagement and which may have subsequently influenced their learning. To identify relevant actions and interactions, I focused on identifying what participants said, experienced, and enacted. I used the following indicators to transcribe and code participant interactions:

Social Interactions – people talking, listening, overhearing, and watching and other physical interactions

Technological Interactions – with, through, and/or around digital technology - touching, looking at, referring to, searching, browsing, and engaging with technology

Material Interactions – touching, looking at, referring to, and engaging with resources and other tools

To identify the context of those actions, I focused on what was going on right before the episode/event of interest, during it, and immediately after. In particular, I identified the positional and spatial orientation of individuals, materials, technology, and other artifacts in the environment, facilitation, programmatic activities/goals, affordances of materials and activities. In addition, I transcribed what participants were attending to, what piqued their curiosity/interest, personal and epistemological connections they may be making, their process of constructing artifacts, and their engagement in conversations.

This process of transcription helped me resolve some of the questions generated at the end of phase 2 about how and what experiences led to learning. It also highlighted gaps in the story, which I then used as suggestions to identify additional data (video episodes or artifacts from other learning topics) that might shed light on answering those questions.

4.4.4 Phase 4: Connecting together the pieces of the learning story

In Phase 4, I identified why the learning developed the way it did and what afforded it happening. To gain this understanding, I identified the specific relationships between the relevant episodes, interviews, and participant-created artifacts in the timeline to construct a temporal story of how the learning developed. I focused in this phase on identifying what parts of participants' experiences (e.g., listening, overhearing, cooking, doing a science experiment) related to what participants later said, wrote, or were able to do.

To the extent possible, my aim was to characterize participants' interests, goals, and focus to understand how they took up the affordances of these contexts. To do this, I identified alignment or misalignment of participants' goals with the goals of KSI: what seemed relevant to participants based on the situation and context of cooking (e.g., perfecting recipes, preparing recipe, getting one's turn), how participants framed the activities in KSI, and the social relationships between participants and the relationships between participants and the facilitators.

Ultimately, the goal of this phase was to understand how the progression of participants' interactions, experiences and environmental contexts shaped and transformed their understanding or capabilities over time. In the process of constructing the learning stories, I identified additional gaps that required subsequent reviewing, transcribing, and coding of additional relevant episodes. Overall, this process allowed me to characterize the development of participants' understanding and capability at the end of 10 or 20 weeks of participating in the KSI program.

The result of this phase was a full set of episodes that made up the learning story. These learning stories illustrated the development of understandings and capabilities over time. Each episode in the learning story may not have been a direct illustration of what participants knew about the targeted science content, but they held information about how the types of interactions and experiences they engaged in helped to develop that understanding.

In particular, these experiences are most often found in the following kinds of episodes where an individual or group was

(1) constructing the artifacts

(2) verbalizing their understanding

(3) demonstrating understanding and/or capabilities

(4) directly engaging in activities or conversations that facilitate or inhibit learning of the content or capabilities;

(5) coming within close proximity to others who are engaged in relevant talk about the science content, capability, or the activity's purpose; and/or

(6) coming within close proximity to others engaging in activities that could contribute to or inhibit learning.

To ensure the learning stories were valid, all my conjectures were grounded in the video transcripts and the actual video footage.

Next, I repeated Phases 1-4 to create a total of 4 learning stories, 2 from each enactment. I then selected one story from each enactment based on the completeness of the story and the existence of episodes to compare and contrast. In particular, I was looking for learning stories whose episodes represented a diversity of participant interactions and experiences and ways of learning in the program. In addition, I was looking for learning stories that could offer me insight into the underlying mechanisms, processes, and configurations that promoted and/or inhibited learning. I used these two learning stories in Phase 5 to create two case studies.

4.4.5 Phase 5: Using learning stories as data to identify patterns in participant interactions and experiences and physical layout, social configurations, and material configurations

The fifth phase focused on why the learning developed in the way it happened on the interactional and contextual level. This phase focused on analyzing these stories using grounded theory (Strauss & Corbin, 1998) to identify patterns of contextual and interactional affordances for learning and the process by which these affordances promoted or hindered the development of learning.

The overarching goal of this phase of analysis was to use grounded theory to develop a substantive theory of how “doing” promotes physical and cognitive engagement in a learning-by-doing learning environment. To do that, I focused on the roles of participant interaction, experiences and environmental context to create my case studies. While the learning stories show what participants learned and the context of that learning, the case studies are more explanatory. They point out the factors that promoted and/or inhibited participant engagement and learning. Thus, I used the patterns identified across the case studies to develop substantive theory about how engagement and learning is promoted or inhibited to address my research questions.

RQ 1. What are the types of interactions and experiences that promote and/or inhibit learning and engagement in learning-by-doing learning environments?

RQ 2. What are the types of configurations that promote and/or inhibit learning and engagement in learning-by-doing learning environments?

4.4.5.1 Open Coding

During the Open Coding phase, the initial phase of analysis using grounded theory, I analyzed the episodes in learning stories. I used grounded theory’s analytic induction to identifying themes of interaction and context in the two learning stories. In this inductive phase of data analysis, I broke the stories up into their interactional and contextual pieces (e.g., conversations with peers or facilitator, constructing artifacts, overhearing science talk). This phase of the analysis was focused primarily on grouping these interactions and contexts together into descriptive themes.

4.4.5.2 Axial Coding

In the Axial Coding Phase, I pulled the data back together by identifying patterns of context, action, and interaction themes that both influence and inhibit learning. Through grounded theory's constant comparison and more deductive strategies, I continued to look across episodes in a single story and across episodes in the other story for similar and divergent occurrences of these patterns. This allowed me to build up more robust patterns of themes and to identify aspects of process that connect these patterns together. I was specifically looking for the ways that these patterns directly or indirectly influenced the learning. Strauss & Corbin (1998) call these relationships causal[6], intervening[7], and contextual conditions[8].

The patterns, themes, and trends I identified in this phase of analysis became the two descriptive lists that I present cases of in Chapters 5, 6, and 7.

4.4.5.3 General Strategy for Analysis:

I also used Strauss and Corbin's (1998) analytic technique of generative question asking to help me really understand what the data was suggesting about instances of phenomena and relationships among phenomena. To aid in the interrogation of the data, I employed the following four analytic questions:

a. What are the social, technical, and material interactions[9] that facilitate or inhibit the process of learning?

b. What affordances of social, material, and technological interactions facilitate and inhibit learning?

c. What are the causal conditions that influence how these interactions arise? And in what situational and instructional contexts do these interactions arise?

d. What are the intervening conditions (i.e., interactions and contexts) that affect how the affordances for interactions that lead to learning arise and are taken up?

The final step of my analysis was in coming up with the primary category with which all other categories are connected. This turned out to be the configurations of learning environments. Once I selected this as my primary category, I organized the other categories around it to tell an explanatory story of how learning develops in KSI that transcends each of the individual stories I identified in phases 1-4. This resulted in the model I discuss in Chapter 8.

4.4.5.4 Selective Coding

My goal through this analysis is to begin building a substantive theory of how learning develops in the KSI program across enactments as a means of identifying how participants learn in learning-by-doing learning environments. Strauss & Corbin (1998) suggest that substantive theories are those theories that are not meant to generalize to broader disciplinary notions; rather, they are meant to describe phenomena specific to a particular group or environment. However, they also suggest that substantive theories help the researcher to ask more refined questions and design more robust investigations to develop more general theories of phenomena. My substantive theory led me to create a model of the influence of the physical, social, and material configurations of the learning environment on the types of participant engagement that are arose in the context of learning-by-doing activities.

4.5 Summary

This method is appropriate for my goals of exploring KSI, as it is a learning-by-doing learning environment through inductively (1) identifying what interactions and contexts influence learning in the program, (2) exploring how these interactions and contexts influence the learning, and (3) detailing under what conditions they influence learning. In addition, this analytic method suits my goal to use the substantive theory and the patterns of interactions and contexts from this analysis to generate new research questions or phenomena to investigate.

In the introduction to Part 2, I highlight and define the patterns I found with respect to participant interactions and experiences and the roles they played fostering different types of engagement. I then introduce the two case studies I use to demonstrate these patterns. In Chapters 5 and 6, I explore these patterns and what affords and constrains participant interactions. In Chapter 7, I delve deeper into the affordances and constraints of the physical layout, social, and material configurations that influence the patterns in participant engagement identified in Chapters 5 and 6.

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[1] I claim that KSI is an environment where learning and technology usage were not the primary focus of participants, thus is an appropriate context to study this research question.

[2] Strauss & Corbin (1998) suggest that substantive theories are theories that are closely related to a specific group or place. They contrast this type of theory with general theories, which are less group and place specific and apply more generally to a wider range of disciplinary problems and issues. Based on my understanding of substantive theories, they are hypotheses that can be springboards for more general theorizing.

[3] The names of the schools and participants have been changed to preserve the anonymity of the participants.

[4] The names of the schools and participants have been changed to preserve the anonymity of the participants.

[5] YWCA – The YWCA is the oldest and largest multicultural women's organization in the world.

[6] "Causal conditions usually represent a set of events or happenings that influence phenomena, (Strauss & Corbin, 1998 p. 131)"

[7] Situational and instructional contexts are a subset of what Strauss & Corbin (1998) term contextual conditions. "Contextual conditions are the specific set of conditions (patterns of conditions) that intersect or dimensionally at this time and place to create the set of circumstances or problems to which persons respond through actions/interactions. Contextual conditions have their source in causal (and intervening) conditions and are the product of how they crosscut to combine into various patterns dimensionally. (p. 132)"

[8] "Intervening conditions are those that mitigate or otherwise alter the impact of causal conditions on phenomena. [They] often arise out of contingencies (unexpected events), which in turn must be responded to through a form of action/interaction.

[9] These interactions can be both those that are purposeful and deliberate and those that are more routine and habituated. Strauss & Corbin (1998) describe interactions as the "how by which personas handle situations, problems, and issues they encounter (p. 13)

PART II:

INTRODUCTION TO THE CASE STUDIES AND PATTERNS OF ENGAGEMENT

1 Introduction to the Case Studies

I present two case studies, one from each enactment. Case Study #1 shows dimensions of engagement that promoted engagement and learning, while Case Study #2 shows dimensions of engagement that promoted and inhibited engagement and learning.

In Case Study #1, from Enactment 1, I focused on how a group of boys developed an abstract and application-based scientific understanding of how yeast works in making pizzas and cookies rise. Their interactions illustrate a close-to-ideal learning trajectory of participants in KSI. All of the boys were consistent participants throughout the 10-week program, and they seemed to be engaged in most aspects of the program as we intended them to be. Participants' verbal and written articulations of their scientific understanding of how yeast makes foods rise seems to draw on their experiences in the small-group and big-group activities. This seems to suggest that they were cognitively engaged throughout the program. The episodes from this case study show the kinds of interactions and experiences that were integral in the development of their science understanding, with a particular focus on how their engagement provided structure and experiences that promoted cognitive engagement.

In Case #2, from Enactment 2, I focused primarily on one participant who joined KSI halfway through the thickeners unit (at week 15 out of 20 of the entire KSI experience) yet still developed some understanding of the science of how starches work to thicken foods. While this participant may not seem like a good candidate to study because of the short duration of her participation, I have selected this case because it highlights what inhibited participant engagement looks like, and it also provides an example of a path to learning science content and scientific reasoning in KSI that we had not imagined when we designed KSI. For example, this case shows that KSI had affordances that supported her learning even though she joined late and shows how other affordances that were intended to help her learn either were missing or went unnoticed. Therefore this case study illustrates factors, interactions, and experiences that promoted cognitive engagement and other factors that inhibited the kinds of engagement intended in KSI. In particular, it illustrates the benefits of certain kinds of redundancy, inherent in KSI's design, for supporting participants who may miss experiences intended to promote learning.

2 The Types of Interactions and Experiences that Seemed to Promote or Inhibit Learning

In examining these two case studies of participant learning and engagement in KSI, I identify three dimensions of participant engagement that I use to organize my presentation: sensory engagement, social engagement, and cognitive engagement. Sensory engagement refers to tactile, visual, taste, and auditory experiences with phenomena and materials. Social engagement refers to collaborations and material coordination participants engage in while designing and constructing artifacts. Times when participants are talking with each other about the activities they are engaging in are examples. Such talk helps participants identify important phenomena and practices, a focus that later aids sense-making. Cognitive engagement refers to the thinking participants are doing as they engage in learning activities and later when they reflect on their activities. Cognitive engagement includes the conversation about changes in artifacts that signify scientific phenomena, reflection on the recipe preparation process, and the connections participants make between their experiences and scientific explanations of their experiences. My division of engagement into these dimensions is undoubtedly an oversimplification of the complex ways that these aspects of engagement interact to characterize participant engagement. However, to highlight the underlying aspects of these dimensions, such a division was necessary.

Sensory Engagement: The sensory engagement I observed included participant interactions like noticing (seeing and touching) phenomena, noticing changes in phenomena, and hearing verbal cues about important things to notice and see and explanations of what they were seeing. It seemed to be the most basic or foundational level of engagement and gave participants both firsthand and secondhand interactions and experiences with phenomena of interest.

Social Engagement: I observed participants in small groups talking about their interactions with materials (e.g., resources and artifacts), discussing what activities they would engage in next, correcting one another's mistakes, and tracking the status of a recipe through recipe reading and material monitoring. I identified this particular set of group practices as forms of participants' social engagement. Within this dimension of engagement, I saw participants participating in these practices as a means to gain firsthand and secondhand experiences in preparation of recipes and carrying out experiments.

Cognitive Engagement: I observed participants engaging cognitively in a number of ways while they participated in KSI. I saw them reflecting, changing the focus and direction of small-group activities, sharing results, trouble-shooting mistakes using science knowledge, using science knowledge to create something new or to tweak something, repeating experiences, and finding interest and value in what they were doing, seeing, hearing, reading, or thinking. These aspects of cognitive engagement gave participants the chance to enact new behaviors, to change their current practices, and to pursue their interests. Oftentimes, these opportunities to engage cognitively were a function of the roles that a group member took on in his/her small group. For example, participants who had both firsthand experiences preparing the recipe and who had observed other aspects of the recipe preparation process were able to reflect on all the aspects of the recipe preparation process and the changes the recipe artifacts underwent. Thus, these opportunities for cognitive engagement were shaped by participants' prior sensory and social engagement. Likewise, cognitive engagement often shaped how participants engaged in sensory and social interactions after their interests were piqued.

The case studies show how these three types of engagement seemed to mutually reinforce each other. For example, readers will see that participants' continuous monitoring of one another (sensory engagement) affected not only how they participated as individuals but also how they collaboratively worked together to coordinate their efforts (social engagement). Participants used this same continuous monitoring pattern to make sure that everything was done correctly when preparing recipes. In addition, participants engaged in continuous monitoring patterns to make sure that their observations and stories were reflective of not just their own ideas but of the collective whole group's ideas (cognitive engagement).

3 Reading the Case Studies

While the case studies I present in Chapters 5 and 6 are primarily focused on illustrating patterns in the roles of sensory, social, and cognitive engagement in promoting or inhibiting learning in KSI, I provide additional information to help you contextualize the episodes I highlight. I begin each case study with some background information about the participants and what they learned in the program. This information is presented to help readers understand participants' personalities, the learning environment structure, and what participants learned. In addition, I raise questions in the introductions to the case studies about how participants' learning developed.

Each case study then consists of a series of analyses of episodes that exemplified patterns in participant engagement that promoted or inhibited cognitive engagement and learning. For each episode, I discuss why the episode is a good example of the pattern I am highlighting, and then I discuss the affordances and constraints that fostered that interaction or experience. In addition, I highlight the roles that activities, artifacts/resources/materials, and facilitation played in these episodes.

By highlighting the patterns and affordances of participant interaction in the context of KSI's design, I aim to establish (1) the degree to which KSI's design provided the necessary structure to promote participant engagement; (2) the degree to which participant engagement provided opportunities for the goals of KSI's design to be realized; and (3) the degree to which participant engagement provided opportunities to bridge the "goal gap" – the gap between participants' goals and the intended goals of KSI.

4 Configurations that Promote or Inhibit Learning

When comparing the cases to each other, I found that opportunities for sensory, social, and cognitive engagement seemed to be influenced by the physical, material, and social configurations of participants' workspaces. Social configurations are the physical ways that participants are arranged in a work space and the position and orientation of those participants to each other, In particular, I found that the types of social configurations that were formed in a workspace seemed to be structured by the physical layout of the space, as well as by the placement of materials and resources in the workspace. In Chapter 7, I identify the types of social configurations in each case study, how they form, and the ways they afford and constrain participant engagement. While reading Chapter 7, it will be important to notice the social configurations of participants and he conditions that give rise to those configurations (e.g., When are they working together or talking to one another? When are they participating separately?)

5 Terminology

Finally, I want to introduce some terminology I use in the next three chapters as I discuss the episodes.

Artifact/Recipe Artifacts are the objects that participants design or construct. For example, if participants are preparing pudding, <u>pudding</u> is the *recipe artifact*. If the participants are carrying out an experiment, the <u>water bottle or container and its contents</u> that results from following the science experiment procedure is an *artifact*.

Resource/Material/Ingredients/Tools are the supplies that participants use to prepare the recipe or carry out the experiments. For example, participants frequently use measuring cups, thermometers, plastic bowls, glass cups, water bottles, and mixing spoons.

Essential Materials are two or more materials or tools that must be used in conjunction with one another to be able to complete a particular preparation task. For example, if a participant needs to measure 1 tablespoon of sugar, the essential materials are the sugar, measuring spoons, and bowl/cup/receptacle to pour the sugar into.

Focal Ingredients are ingredients that the participants are learning about in KSI. For example, when participants are learning about leaveners, the focal ingredients are yeast, baking soda, baking powder, and eggs.

Cooking Phenomena are instances where the recipe artifact changes states, e.g., when water begins to steam or butter melts or egg whites are whipped into airy foam.

Important Cooking Phenomena occur when focal ingredients are used and change the state of the recipe artifact. For example, when the participants make brownies with different types of eggs, the cooking phenomena are the effects that result after the eggs are added to the batter: smoother and shinier batter texture and/or the holding together of all the other ingredients that were separating before. In addition, it is a cooking phenomenon that the brownie batter hardens in a solid and rises when baked. Another example is when the pudding begins to thicken after being heated for some time.

Science/Scientific Phenomena are observable occurrences of the process or changes in state of artifacts that show how an ingredient works. The chemical reaction created when participants add baking powder to water and the water begins to fizz is an example of a scientific phenomenon. Other examples include the thick light brown airy foam that is created when yeast is activated in water and placed in a container with sugar and signifies the phenomenon that the yeast are reproducing; and if this container happens to be covered by a balloon, the inflating balloon is created by the science phenomenon of yeast producing carbon dioxide.

Recipe Reading includes a number of different ways participants read a recipe or experiment procedure and use it to coordinate the preparation of the recipe artifact/artifact. Recipe reading can be done silently for private benefit or aloud for the benefit of or participation by others.

Recipe Preparation Process is the process by which participants prepare the recipe or carry out the experiment they planned previously. It includes reading the recipe and/or hearing others read the recipe, then gathering materials and ingredients and performing the tasks in each step. It includes the decisions or changes that are made in the moment or the particular ways that participants do things in their group to prepare the recipe.

Reflection is when participants think about what they are doing and why. It may happen during activity (reflection-in-action) or afterwards (reflection-on-action).

(1) **Written Reflection** includes recording observations, writing stories about their experiences, and writing plans for how to change a recipe based on what they know about how ingredients work. Artifacts that result from written reflection are experiment designs, observations, stories, explanatoids (mini-explanations), and recipe-change planning pages. These written reflections can be hand written on paper or typed into web pages using the KSI software.

(2) **Oral Reflection** includes the stories participants tell each other about their experiences, the verbal articulation of observations, the explanations participants come up with to explain why their artifacts came out the way they did, and conversations participants have with each other or facilitators about their experiences.

(3) **Drawn Reflection** is the ideas that are captured in participants' drawings or illustrations. Participants often use drawings to explain their understanding of the science and cooking phenomena.

Interaction is the sensory, social or material contact or observation participants have while participating in activities. Examples of **social interactions** include people talking, listening, overhearing, and watching and other physical contact or exchanges between people. **Sensory/material** interactions include touching, looking at, referring to, and engaging with resources and other tools.

Experience is the collection of interactions that characterize participants' engagement, and includes what they saw, heard, and understood in a given situation. For example, if a participant was a part of the preparation of process for making brownies with one-egg, the participant has had an experience of making brownies.

Opportunity is a chance for a participant to engage in an activity or interaction in a certain kind of way. Opportunities exist because of the structure of the activities, activity sequences, and facilitation.

Affordance describes perceivable aspects of a task, situation, or objects. For example, an affordance of a situation might be the opportunity to see or hear what others are doing. An affordance of a task might be the opportunity for a participant to shift his/her current activity to perform the task. The affordance of an object is the opportunity it makes available to perceive its state or to use it in a particular way. For example, clear containers have affordances for seeing their contents from multiple angles and distances, whereas opaque containers afford seeing the contents only from an opening in the container. Door handles have affordances to be pushed or pulled (Norman, 1988) and mixing spoons have long handles that afford grasping and rounded and scooped structures that afford mixing ingredients in a bowl.

Pattern is a repeatedly observed participant interaction or experience or sequence of interactions or experiences. For example, participants in Case Study #1 were observed regularly monitoring the activities of their group members and the states of artifacts. They used these observations to make decisions about how to participate, and they referred to these observations as they reflected on the ways artifacts changed over time.

In describing the patterns that I notice, I use the following terminology to discuss the participant interactions or experiences that I saw and the relationships between them.

Influence means one thing happened and then another happened, and an argument can be made that the first affected the second.

Promote means I observed a positive relationship between instances of participant interaction/experience where one thing positively influenced the occurrence of the other.

Inhibit means I observed a negative relationship between instances of participant interaction/experience where one thing negatively influenced the occurrence of the other.

6 Overview of Upcoming Chapters

In Chapters 5 and 6, I present episodes from the two case studies I've introduced and highlight the dimensions of engagement that promoted and inhibited learning. In Chapter

7, I present a cross-case analysis that shows the roles that social and physical configurations in the environment played in promoting these experiences.

CHAPTER 5

CASE STUDY #1: DIMENSIONS OF ENGAGEMENT THAT PROMOTE LEARNING DURING SMALL-GROUP ACTIVITIES

Figure 5.1 Brett and KJ's final poster of what they learned about yeast

This case study illustrates ways that dimensions of engagement interact to promote learning during KSI small-group activities. In this case study, I focus on how one group's sensory and social engagement in KSI small-group activities fostered cognitive engagement that seemed to allow them to learn about yeast as an organism and a leavener, and to apply this knowledge in the service of perfecting recipes.

This case study illustrates a close-to-ideal learning trajectory of participants in KSI. The group of boys (Craig, Brett, and KJ, and William) in this case study participated in all of the designed KSI activities, keeping themselves engaged throughout the program. Through the analysis of the changes in their verbal and written articulations of their understanding of the science of how yeast works, it seems that they came to understand the content deeply, and that their understanding was both context-specific and abstract. Furthermore, it is clear that the boys' learning developed through their participating in the designed KSI activities. So, the question is: What types of interactions and experiences were responsible for promoting learning among this group of participants?

5.1 Background

5.1.1 Learning

Before we begin to address the question of how the boys' learning developed in this learning environment, I want to highlight what this group of boys learned in KSI. This is necessary because I will not be covering what and how they learned in chronological order, for the focus of this chapter is the discussion of the dimensions of engagement patterns.

At the start of the program, the boys all seemed to know that yeast makes food rise, but they did not know how or why. By the end of the program, they understood that baking soda, baking powder, and yeast are all leaveners. Furthermore, they understood that baking soda and baking powder are interchangeable with yeast in recipes because these ingredients do the same thing: produce carbon dioxide bubbles in food that can be captured to make foods rise. They also understood some of the science behind how these ingredients work.

For example, the boys learned that yeast needs water to activate it and then it needs to eat sugar to produce carbon dioxide and reproduce from their observations of the yeast-air balloon artifacts they created and the science explanations they heard and read about from materials we provided them. Evidence that they understood this is reflected in artifacts they created throughout the program to demonstrate their understanding as well as verbal explanations they gave to the facilitator to justify their decisions when applying their understanding in later activities.

They understood that yeast and baking powder work differently, with respect to speed and the amount of bubbles these ingredients produce in the dough. They also understood that baking soda and baking powder participate in chemical reactions to produce carbon dioxide and that water is needed to start those reactions. On the other hand, the boys understood that yeast is a live organism, a fungus, so it needs time to produce CO_2, and that the organism will produce its CO_2 only after it eats sugar. They also learned that they did not have to conserve proportions of water, sugar, and yeast for the yeast to work.

In addition, they understood that the dough plays an important role in making pizzas and cookies rise because the dough acts as a structure to trap the carbon dioxide produced by the yeast, baking powder, and/or baking soda. They came to understand this through seeing their dough increase in size when they let it rest and seeing the balloon on their yeast air-balloon inflate. This conceptualization was reinforced through an explanation the facilitator gave relating the inflating balloon on the yeast-air balloon to the dough and how both trap the carbon dioxide created by these leaveners.

The boys were also able to use their understanding of how yeast, baking soda and baking powder work to make thick crust pizza and cookies with yeast. Since they understood the science behind how these ingredients work, they were able to use their science understanding as a basis for adjusting certain ingredients, and not others, as well as recipe instructions to perfect their recipes. For example, when they made cookies using yeast, they dissolved the yeast in warm water and let it begin to reproduce; adding that solution to the rest of the cookie ingredients only after the yeast had been reproducing for a while. They did this instead of simply substituting the baking powder for yeast in the recipe because they took into consideration the differences between how the two ingredients work.

A summary of their understanding is showcased in their poster at the opening of this chapter in Figure 5.1. The figure shows the poster that Brett and KJ made for their presentation during the last session of the leavening unit to explain to their parents and friends how yeast works. The food drawings are pictorial representations of the results of their Retry Day explorations of yeast. As such, the elements on the poster are reflective of particular recipes the boys prepared to learn about how yeast makes foods rise and test their hypotheses about how varying the amount of yeast in a recipe changes the height of their food. For example, the poster features anthropomorphic depictions of yeast, sugar, and water in an equation that equals rising and the words “yeast needs partners to rise”. While some critics of science education might suggest that anthropomorphic depictions of science can lead to misconceptions, we found that such depictions served as memory aids for the participants and help them begin to consider the relationships between the various ingredients and their role in making foods rise. Also included on this poster are drawings of a “tall” thick crust pizza slice and a “huge” cookie under the statement “more yeast equals”. These drawings and statements reflect the boys’ experience and results of trying out their hypothesis that adding more yeast to the pizza recipe and substituting yeast for baking powder in the cookie recipe would make the foods come out bigger and taller. Under these pictures reads “less yeast equals” and a drawing of a “thin” crust pizza slice. These drawings and statements reflect the boys’ experience of trying to add less yeast to make a thin crust pizza. The content of this poster and other artifacts suggests that KJ and Brett learned through their participation in the designed activities, conversations, and interactions with resources and materials we intended by the design of KSI.

5.1.2 Description of Learners

Three of the four participants in this group, Craig, Brett, and KJ, reported that they liked science, eating, and cooking at home. William was the only participant who did not have previous cooking experience.

Craig was focused and serious, yet also playful during down time. He asserted himself as the self-appointed leader of this group and was often found delegating tasks, as well as appointing tasks for himself. He was deeply engaged in both the cooking and the science conversations, and he made a number of connections between the science activities and the cooking activities. Craig often masterminded their recipe alterations and preparations, and he used the science understanding he’d developed to this end.

Brett was jolly and often smiling, laughing and making his experiences into songs. Brett and Craig were always very hands-on in preparing the recipes. Thus, they were often vying for turns at stirring, kneading, measuring, and other recipe preparation activities. Brett was deeply engaged in both the cooking and the science. He was also often engaged in cross-group conversations, resulting in overhearing important details about the science and the cooking activities, even when they were directed at another group. Brett was skilled at making connections between his KSI experiences and those outside of KSI.

KJ was quiet and responsible. He often reminded the group about how much time they had left before they could do the next recipe step and that they needed to record observations. He enjoyed watching his group work and making observations, which served his group well, as the other three members of his group were always competing for their turn to stir, knead, or otherwise prepare the recipe of the day. Thus, KJ often stood in the background and took in everything that was going on in the group. KJ's attention to detail and cooking experiences often manifested themselves in ways that allowed him to make connections between what he was doing in KSI and his past experiences from home or school. KJ was usually very involved in the science activities of the group. He also had experience cooking at home with his dad. KJ often contributed to the big-group discussions through sharing his science understanding. KJ was often the scribe because he remembered that they should record what they were noticing. He often used this writing as a way to participate and make a contribution to his group.

William was a bit silly and less focused than his other group members. In addition, he was often caught using the wrong measuring cup or spoon because he did not have that much cooking experience. Consequently, he often busied himself cleaning or taking pictures of the recipes in preparation. When he contributed in the big-group conversations, he often misunderstood the question or the reasoning behind the decisions his group had made. During these discussions, both the facilitator and other participants helped William understand the correct answer and the reasoning behind it.

Overall, this group worked very well together. In general, Brett and Craig did the majority of the cooking and science experiments. When given the opportunity, William and KJ stepped in before the other two group members quickly displaced them. William and KJ's lack of participation in the preparation process was not because they were not interested. Rather, it was due to Brett and Craig dominating the activities and leaving little room for the two other boys to participate.

Important to that development, I found, were the ways the boys engaged their senses when preparing the recipes and science experiments and that this engagement piqued their interest to purposely monitor their environment. Initially, the boys wanted to make dishes successfully and each boy wanted his turn engaging in the recipe preparation. Very quickly, however, the boys seemed to become interested in noticing changes in their recipe artifacts (the dishes they were making) and science experiments. These interests seemed to push them toward monitoring the states of those artifacts, even at times when they were engaged in other activities. They also became interested in what others were doing and what they were producing. These interests seemed to push them towards monitoring the activities and artifacts of other groups. As a result of monitoring the activities of others and the conversations that ensued, they became aware of new ways of engaging in preparation processes, mistakes they were making, and phenomena of interest. Eventually, they seemed to recognize the value of their monitoring and to engage in it more intentionally. Once they got started with the pattern of continuous monitoring they were taking on inquiry goals and experiencing science phenomena intended by the program. The three dimensions of engagement -- sensory, social, and cognitive – became fluidly interwoven with each other, productively driving each other. The contribution in this chapter is my analysis of how that happened in this enactment of KSI and what influenced that development.

5.2 Patterns of Sensory Engagement

Ensuring that participants have adequate firsthand exposure to the science phenomena while engaged in hands-on inquiry experiences, requires getting them (1) to notice (see and touch) phenomena; (2) to appreciate changes in phenomena; and (3) to hear verbal cues about important phenomena or participant interactions to notice and see. While activities and projects were specifically designed to allow participants to have firsthand experiences with science phenomena, the boys were often more concerned with the "doing" involved in the recipe preparation process and "having their turn" than they were with noticing important phenomena. This suggests that while the goals of activities were meant to engage participants cognitively, participants were often more motivated to engage physically for the sake of having their turn. *However, through the tactile, visual, and verbal/auditory aspects of sensory engagement employed by the boys to ensure that they had their turn, they gained a wealth of firsthand experiences that helped them later learn about the phenomena and the science.* Since this group's goals were different from the intended activity goals, it is important to understand the ways their sensory and physical engagement provided opportunities for them to engage cognitively. Hence, I have organized the presentation of the patterns in sensory engagement according to tactile, visual, and verbal/auditory aspects of engagement, to provide the necessary foundation in explaining the participants’ social and cognitive engagement during recipe preparation and later reflections.

I identified two main categories of sensory engagement patterns that I observed regularly that led to interesting subsequent behavior and later cognitive engagement:

1. Sensing in the context of doing (preparing the recipe and/or carrying out the science experiment)
    - Touching, tasting, smelling, picking up of artifacts
    - Watching (looking at) artifacts changing over time and noticing cooking and science phenomena
    - Watching (looking at) others while they work and recognizing differences between one’s own activities and the activities of others
    - Hearing verbal cues that signal other participants’ interest in the activity at hand
    - Listening to verbal cues that signal the direction of activity
2. Sensing in the context of piqued interest
    - Touching, tasting, smelling to find out more about the artifact because of personal interest (e.g., wanting to know what something tastes, feels, or looks likes not just because one is told to do these things)
    - Continuous monitoring of artifacts for interesting changes recognized earlier in the context of doing
    - Continuous monitoring of others to see if there is something else going on that they could participate in

- Listening to and giving verbal cues that signal other participants' interest because of one's own interest (e.g., listening for or verbalizing sounds of excitement: "Whoa!" and "Wow!")
- Listening to and giving verbal cues that signal the direction of the activity because one has a vested interest (e.g., what ingredients are needed and what are the next steps or task we will be completing)

These two lists may look very similar. However, the first list is what happens and what participants do to complete the recipe preparation process and the second reflects their purposeful engagement in these activities. Each seem to have different impacts.

5.2.1 Tactile

In many instances tactile engagement provided the boys with the kinds of firsthand experiences they needed to reflect upon in order to understand the science content underlying the hands-on activities. Tactile engagement also promoted their noticing of phenomena of interest and changes in artifacts. I found two patterns related to tactile engagement:

1. Tactile engagement led to noticing phenomena and changes in artifacts that in turn piqued interest and affected later behavior
2. Tactile engagement led to discussions of and reflection on connections between experienced phenomena and science content

These patterns happened in context of preparing a recipe or running an experiment or in the context of participants already having interest in a particular aspect of the activity. In the context of preparing a recipe or running an experiment, participants tended to touch, taste, and smell the artifacts they were preparing, which led to them noticing cooking and science phenomena that provided them with the firsthand experiences necessary for later reflection. For example, participants noticed that the yeast was producing foam in the yeast-air balloon artifact so it made them want to touch it. When they touched they noticed that it was warm and later when they found out that yeast was a living organism, they connected the warmth of the bottle to the fact that living creatures are warm.

In addition, these forms of tactile engagement piqued their interest to continue to engage in these ways. When these patterns of tactile engagement occur in the context of participants' interests, participants tended to purposely re-engage physically and curiously with artifacts which then led to conversations within and across groups and wondering about what they were experiencing. For example, once the participants found out that the water bottle was warm they kept picking it up throughout the session. Similarly, they had repeated conversations about the yeast-air balloon artifact being a pet.

Episode 5.1 illustrates aspects of both of these patterns. This episode occurred toward the end of the first KSI Leavening session. The group had just finished preparing the pizza dough and set it aside to rest. In the meantime, they were carrying out a yeast-air balloon experiment. The yeast-air balloon experiment was designed to help participants see the gradual changes created as yeast metabolizes sugar and produces carbon dioxide to blow up the balloon. In addition, the experiment ideally allows the participants to experience yeast as a live organism. To create this artifact, the participants put yeast, sugar, and warm water in a clear water bottle and capped it with a balloon. They then set it aside for later. The activity was designed to highlight the science behind yeast and how it makes pizza dough rise.

In the episode, Brett, KJ, and Lisa (from another group) are cleaning up when Brett notices his balloon has inflated. He goes over to it and tries to listens to it and then begins a discussion with Lisa about the bottles. She begins discussing it as a pet. Brett touches it and notices it is warm.

Episode 5.1:
Session 1:
1:05:36
Brett: [looks at, picks up, and tries to listen to the yeast air-balloon]
KJ: [Shoos him away]
Brett: [Picks up the pizza timer and looks at it, then puts it back down and focuses his visual gaze on the balloon]
Lisa: [Is talking to Brett about the bottle and balloon, most of which is inaudible. But she leans in over the table from where she is standing out of view of the camera and runs her hands down the bottle] “It's like a pet.”
Craig and KJ: [Cleaning up the flour on the table]
William: [Helping them clean as well]
Lisa: [Telling them something about what she named her water bottle and balloon] “…Fungi. So what did you name yours?”
Brett: [Picks up the bottle and looks at it. Brett exclaims] “It's warm!”
Craig, KJ, and William: [look up from what they are doing and look at Brett]
William: [Pointing at the bottle] “I’ll take that home.”

Brett’s noticing of the water bottle being warm is consistent with the idea that yeast is alive, as seen in the conversation between Brett and Lisa about treating the artifact like a pet. The fact that yeast is alive is an essential part of the explanation they encounter later for why the balloon inflates and the pizza dough rises. While Brett may or may not be making that connection now, his noticing of the bottle’s warmth sparks his interest in a science phenomenon: yeast blowing up the balloon. Throughout the remainder of the session he continues to pick up the bottle and examines what it looks like and how the foam height and balloon are increasing in size. At the end of the session, the facilitator gives a short explanation of how yeast blows up the balloon. As evidenced by the poster he makes on week 10, Brett eventually connects the experience of interacting with the yeast air-balloon to his understanding of yeast as an organism and how yeast functions as a leavener. Here, tactile engagement played a crucial role in sparking a participant's interest and cognitive engagement beyond just physical participation in the recipe preparation process.

From this episode, you can see that Brett's interest in the water bottle was driven, first, by seeing the inflating balloon, and then by feeling its warmth. Once his interest was piqued, he began regularly monitoring this artifact and periodically glancing down at it, picking it up to peer in through the clear container and putting it up to his ear to hear if the changes happening in the bottle make any sound. In other episodes you'll see this continuous monitoring in more detail. It was not just tactile monitoring but visual and auditory monitoring that led to participants having discussions over and over again. Brett's initial interest and his *continuous monitoring* of the balloon and its bottle were facilitated by the *openness* of the clear water bottle and the observability of the balloon changing its size and the artifact's *persistent presence* in the participants' workspace while participants engaged in other activities.

Many of the episodes discussed in this chapter have elements of tactile engagement. This engagement ranges from touching and tasting sticky dough to feeling the differences in textures of different dough and of dough over time. *However, no matter what form participants' tactile engagement with material artifacts, the engagement gave them experiences to connect to and to reflect upon later.*

5.2.2 Visual

Visual engagement, like tactile engagement, provided participants with additional experiences with phenomena. I identified 6 patterns of visual engagement among these boys:

1. Looking at artifacts promoted awareness of phenomena, piquing interest and often leading to discussions about changes in the artifact overtime
2. Looking at a set of artifacts led to awareness of phenomena, piquing interest in and often leading to comparisons and discussions about the differences
3. Seeing peers carrying out activities led participants to imitating those same behaviors
4. Seeing peers carrying out activities inspired the participants to engage in new ways
5. Seeing peers carrying out activities led participants to recognize mistakes that either the participant was making or that others were making
6. Overall, piqued interest (in a phenomenon/artifact or a peer doing something) led to intentional continuous monitoring

5.2.2.1 Watching of Artifacts

In general, the boys' visual engagement promoted an ongoing awareness of each recipe artifact's state and history. Watching artifacts was one of the primary ways in which the boys engaged in KSI activities. Their watching of artifacts led to: (1) piqued interest; (2) noticing of phenomena; (3) conversations about the artifacts and their history; and (4) comparison of artifacts at different stages of development, or with different characteristics. These four types of participant interactions/experiences were really important cognitively because they gave the boys opportunities to experience and reflect on important science phenomena. These four interactions/experiences are also important because they are the types of interactions and experiences the science education literature suggests learning-by-doing activities are good at affording (Chinn & Malholtra, 2001).

In Episodes 5.2 through 5.3, we see these four participant interactions/experiences happening in the context of the boys' group and a girls' group working next to each other while they prepared their pizzas for the oven and cleaned their worktables. While they were doing this, the balloons on the bottles of their yeast-air balloon artifacts were inflating. In Episode 5.2 the boys noticed their balloon was inflating and begin examining their bottle and noticed that the yeast was creating light brown foam in the yeast-air balloon water bottle artifact. In addition, the boys watched as Christina adjusted the balloon on the girls' bottle, securing it to the bottle opening. The boys became interested in the girls' bottle and walked over to see what Christina was doing.

Eight minutes later Episode 5.1 happens. Recall that Lisa from this girl's group became interested in the boys' bottle, and Brett discovered that it is warm. Two minutes after that, Episode 5.3 begins. Lisa realized that the girls' balloon had now begun to inflate. Lisa picked up her bottle and she and some of the other girls in her group examined it. Brett saw them and picked his bottle up. A few minutes later, as they all were continuing to examine their bottles; Brett looked at the girls' bottle and exclaimed that the girls' balloon had inflated like his group's balloon did.

I begin by presenting Episode 5.2, the earliest episode. There are four interactions to notice in Episode 5.2, (1) Brett notices that their balloon has inflated. (2) The other boys come over and they examine together what else is going on in the bottle (the foam). (3) The boys discuss the changes in the solution in the bottle and in the balloon. (4) The boys look over at the girls' bottle and notice that it is not blown up and that Christina is readjusting the balloon.

Episode 5.2:
Session 1:
57:39
[The boys' balloon has inflated a lot]
Brett: [Looks at the yeast-air balloon artifact and notices the inflating balloon] "Wow, look at our balloon."
KJ and Craig: [Both direct their attention to the balloon]
William: [Is on his way back to the table]
Brett: [Then looks at the foam and says while pointing at the foam in the water bottle] "Look at how high it is getting. It used to be only up to there."
KJ: [Bends down and looks at the water bottle at eye level]
Brett: [Plucks the balloon and it wobbles back and forth]
Craig: "No, it used to be up to there." [while pointing to a lower point on the bottle]
Christina: [Is on the other side of the table trying to tighten the girls' balloon over their nozzle]
William: [Leans in over the table and tries to help KJ tighten the bottom of the girls' balloon over the nozzle]
57:49
Christina: [The balloon comes off of the girls' bottle and air from the balloon and bottle escape]
Craig: [Walks over and is now standing by Christina watching her fix the balloon, then he runs off]
William: [Runs in the direction of Craig]

This episode illustrates that the sizable inflation of the balloon, a significant change in the artifact's state that Brett visually sensed, cued Brett to look more carefully at the bottle and then notice the height of the foam. This noticing then sparked a conversation among the rest of the boys about the height of the foam over time. Each boy then demonstrated his understanding of the artifact's history by verbally and physically pointing to the physical bottle. These interactions facilitated conversation and negotiation that encapsulated the history of the foam height within the referenced artifact.

It may seem that there is not more to point out about this episode. But notice that while this is the first time they are publicly noticing and discussing the bottle, they each have some ideas about what has been happening over the past few minutes. Their argument about changes in the height of the foam presupposes that each had been monitoring the yeast and the balloon during that time, consciously or unconsciously. Each boy had been at least unconsciously measuring and keeping a history of the height of the foam in the bottle.

In other words, though they might not have been conscious of it (or maybe they were), the boys had been continuously monitoring the status of the bottle and balloon as they were engaging in other activities. As pointed out in the discussion of tactile sensing, this could only be happening because of the *persistent presence and open affordances* of the transparent bottle as the learners were working on other tasks. The importance of this point will become clearer later in the chapter. While Episode 5.2 shows how noticing a change in an artifact promoted discussion of changes over time, Episodes 5.3 and 5.4 highlight how the delayed inflation of the girls' balloon encouraged Brett's deeper interest in his artifact and how it compared to the girls' balloon.

Episode 5.3:
Session 1:
1:07:32
[The girls' balloon is finally blowing up]
Lisa: [Picks up her bottle] "Look. It's blowing up."

Amber and Alice: [Are at the table watching as well when this happens]
Christina: [Walking by the boys' side of the table says to the girls] "That's good." [She then continues walking with a bowl of water to another table]
Erica: [Takes the bottle and holds it up high]
Lisa: [Lisa picks up the girls' bottle again]
Brett: [Picks his group's bottle up at the same time that Lisa picks up the girls' bottle]
KJ: [Takes the bottle from him] "Put it down."

Episode 5.4:
Session 1:
1:09:26
Brett: [Looks at the girls' balloon and points in the direction of the girls' yeast-air balloon artifact] "Look, theirs is getting like ours is."

In Episode 5.3, the inflating balloon caught Lisa's and Brett's interest as they continuously watched the artifacts in their workspaces. This encouraged Brett to take a deeper interest in his own artifact, which shifted his participation away from the cleaning the other boys were doing to the girls' side of the table where he watched Lisa and her group.

Then in Episode 5.4, Brett's continuous watching of the girls' balloon prompted him to make a comparison between the girls' balloon and his own group's balloon. This comparison of artifacts was afforded partly through the fact that the artifacts were at different phases of development, so it provided a natural contrast.

Together, Episodes 5.3 and 5.4 highlight a common pattern I noticed throughout the data, where the watching of artifacts over a period of time promoted new interactions with participants' own artifacts and comparison between them and other artifacts. As stated earlier, this was possible because multiple artifacts were persistent in the workspace and open for observation. Later in this chapter, I will present a model showing affordances of continuous monitoring for promoting deep cognitive engagement; these examples will feature in that model. The blue blocks represent the underlying participant interactions necessary to achieve the participant interactional and cognitive goals of the activities and KSI design in the purple blocks. The peach blocks are the necessary outcome of the activity for participants to be able to actively participate in the next activity. Under each block is a list of affordances and influences that fostered the participant interaction or experience in the blocks.

In Figure 5.2, the blue blocks represent the underlying participant interactions necessary to achieve the participant interactional and cognitive goals of the activities and KSI design in the purple blocks. The peach blocks are the necessary outcome of the activity for participants to be able to actively participate in the next activity. Under each block is a list of affordances and influences that fostered the participant interaction or experience in the blocks.

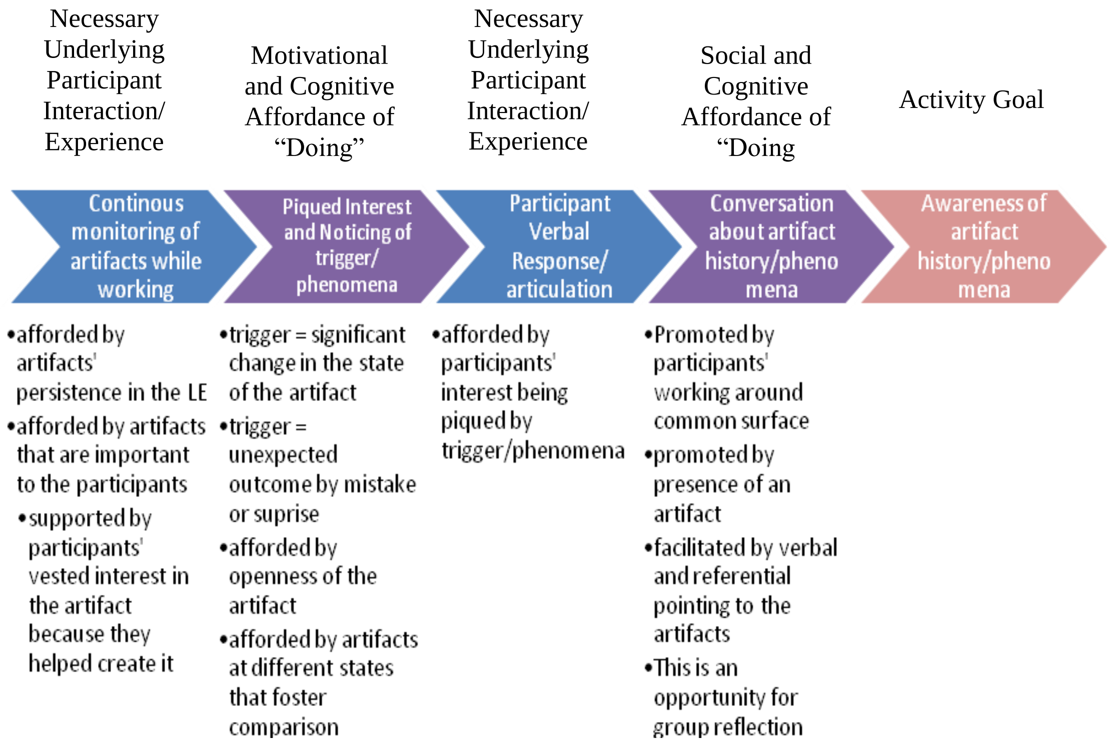

Figure 5.2 Outline of Continuous Monitoring of Artifacts

In summary, Episodes 5.2, 5.3, and 5.4 highlight a common pattern in participants' continuous monitoring of artifacts over time, which piqued participants' interest, and then promoted ongoing awareness and reflective discussion of the changes in recipe artifacts and recipe preparation process. These participant interactions and experiences were influenced by the "open affordances"[1] of the artifacts and the artifacts'

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[1] After Donald Norman (2002) and Hutchins (1995), "open affordances" are aspects of artifacts that make visible how to use an artifact or that make visible important phenomena, interactions, or actions. For

persistent presence in the workspace. Figure 5.2 (above) highlights this continuous monitoring pattern and the affordances that each element in this pattern played, or was influenced by.

Figure 5.2 highlights several ways in which the KSI design provided the necessary structure to promote the types of participant interactions and experiences necessary for them to gain an awareness of artifact history/phenomena. Artifacts were purposely left in the workspaces of participants so that they could observe them while they performed other parts of the recipe preparation process, with the hope they would talk about them. We also hoped that they would want to observe the changes in these artifacts because they helped to create them. To ensure that they would observe them and notice changes in the phenomena they were meant to demonstrate, we designed the activities and artifacts so that they were "open", and would show significant change in the state of the artifact, and unexpected outcome, by mistake or surprise. We also hoped that if they saw something interesting they would share it with their group members. We grouped them in small groups to provide a more comfortable way for them to talk about what they were observing and doing, in a way such that all group members might be heard.

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example, a see-through bottle allows someone to see the contents of the bottle, and as such, it affords monitoring.

In addition, Figure 5.2 highlights the degree to which continuous monitoring of artifacts provided opportunities for the goals of the KSI design to be realized. In particular, notice that all other blocks derive from the continuous monitoring block. It's this monitoring that gives the participants opportunities to track artifacts and the recipe preparation process. And through this tracking, participants' interests are piqued, phenomena noticed, and conversations started.

Continuous monitoring played an important role in providing a bridge between the participants' interactional goals and the KSI-designed goals. The participants' goals seemed to center around getting their turn to complete a step in the recipe preparation activity, or ensuring that all the steps were completed and done correctly. The KSI activity goals were for participants to observe what changes the recipe and the science artifacts underwent as they added each ingredient, and how they changed over time. We wanted the activities to pique their interest, and we wanted them to have discussions. Continuous monitoring of artifacts provided a bridge between these two goals, in that the attention used to find an opportunity to participate also placed the participants in the right position to make passive observations of how the recipe was being prepared, and the changes it was undergoing. These observations were essential for them to gain an awareness of artifact history, and to be exposed to the phenomena to be understood.

In summary, participants' continuous monitoring of artifacts, which was supported by their observable ongoing presence, was a major catalyst in achieving the activity goal of KSI (i.e., awareness of the artifact's history and exposure to the phenomena) by providing the necessary support to fully take advantage of the affordances of learning-by-doing activities (e.g., motivational, social, and cognitive). In particular, continuous monitoring of artifacts provided participants with opportunities: (1) to have their interest piqued (Episodes 5.2, 5.3, and 5.4); (2) to notice phenomena and changes in phenomena (Episode 5.2); (3) to have conversations about the artifacts and their histories (Episode 5.2); and (4) to make comparisons between artifacts at different stages of development, or with different characteristics (Episodes 5.4 and 5.2).

5.2.2.2 Watching People Within and Across Groups

Like continuous monitoring of artifacts, *continuous watching of other participants* within a group and/or across groups promoted: (1) meaningful observation and conversations between participants; (2) mimicking of the activities of others; (3) changes in participants' own ways of participating; and (4) recognition of appropriate materials and mistakes.

Recall that in Episode 5.1, Brett's fascination with the water bottle attracted the attention of Lisa from the adjacent girls' group. Lisa's piqued interest caused her to walk over to Brett's table, which started a dialogue between them about the yeast being alive and the water bottle being like a pet. Their discussion then attracted the attention of Brett's other group members who had been busy cleaning up the table.

This episode also highlights one way that continuous monitoring of others changed participants' ways of participating. In this episode, Lisa and William shifted their activity away from what they were doing to noticing what Brett was doing; this allowed them to have a conversation about the artifacts.

This episode is particularly meaningful because at this time William was cognitively inactive and not focusing on the water bottle or on what was going on inside the bottle. However, the conversation between Lisa and Brett was powerful enough to spark his interest, and to prompt him to express this interest in the form of a declaration to take the water bottle home as a pet. Additionally, overhearing this conversation provided an opportunity for William to possibly think about yeast as alive. Thus, continuous monitoring of other people allowed William to attend to the conversation between Lisa and Brett, and to notice that the water bottle was changing.

Likewise, in Episodes 5.2 and 5.3, *watching people* as well as artifacts was a major component of what made the episodes important, since participants *observed the practices of other groups, thus leading to further observation and comparison*. Recall that in Episode 5.2, Brett picked up the water bottle after watching Erica and Lisa (from the girls' group) lift up their bottle from the table. Then a couple of minutes later in Episode 5.3, Brett's continuous watching of the girls' interactions and artifacts led Brett to recognize a significant change in the size of the girls' balloon, as compared with the boys' balloon.

Notice that the shift in Brett's practices, from just standing around watching, to becoming more active by imitating the interactions of Lisa's group with their water bottles, was cultivated by his continuous monitoring of what they were doing. Furthermore, Brett's continuous watching of Lisa's group encouraged him to take a deeper interest in his group's water bottle, and his interest promoted comparison of the two artifacts. Thus, continuous watching and his change in participation were beneficial for highlighting "what" was important to notice. In addition, continuous watching of others over time provides a natural avenue for comparison of artifacts across groups. Moreover, the comparisons made here during the small-group time were not planned; that they arose naturally and were very influential in driving learning were important to notice, because they supported our goal of getting participants to make comparisons between artifacts during the big-group discussions.

While change in participation in Episode 5.3 is only a mimicking or copying of the behavior of another group, Episode 5.5, also from Session 1, highlights the way that continuous watching of other groups sparks both mimicking and a complete change in the behavior of the watching group, leading to the adoption of the activity goals of making observations of the recipe preparation process. In this episode, Brett and Craig were preparing the pizza dough as KJ and William looked on. While KJ and William observed the recipe preparation process, they noticed the girls working beside them were in the process of tasting the dough. The idea that tasting the dough was "OK" sparked William and KJ's interest in tasting their dough and then in describing its taste and texture as well.

Episode 5.5:
Session 1:
30:00
Girls at the adjacent table: [The girls from the group next to the boys begin tasting their dough since it was all over their hands]
One of the boys from the group to the girls: "You're tasting it?!"
KJ: [Announces with his hands covered in dough] "I'm licking my fingers." [While William pinched off pieces of the dough] "I'm going to describe what it tastes like."
KJ and William: [Taste the dough]
Brett: "I'm not tasting it."
William: "Chewy, but…" [Then stops talking and looks at KJ with a whimsical look]
KJ: "Chewy, but like [pause] chewy!" [While looking off and with a thought-engrossed look on his face]
William: "Chewy, but a little bit. A little bit. It has a taste of salt." [He says this while pointing at KJ in a manner that suggests this is his well thought out conclusion]

The outcome of KJ and William's continuous watching of both their group working, and the girls' group, allowed them access to the notion that they could taste their dough. Moreover, it immediately affected their behavior, by prompting them to stop what they were doing to engage physically with the dough that they were previously just looking at, and to have a dialogue about the taste and texture of the dough, a goal of the activity. In fact, we had provided them with a chart that included the suggestion that they investigate the taste and texture of their dough, but their desire to use the chart was sparked only after witnessing the other group physically interacting with their dough. Prior to this episode, the group had not written anything on the chart and it was not the focus of any of their conversations.

In addition, KJ and William's tasting of the dough and recording of their observations about its characteristics on the chart became ways both to participate in the activities and to initiate reflections on their own terms. Continuous monitoring gave KJ and William a new way to participate in the activities of their group and to adopt the goals intended by the activity. They then progressed from investigating the taste and texture of the dough to discussing and even recording their observations.

Within-group watching of other participants also promoted identifying phenomena and new ways of participating. In addition, within-group monitoring of other group members promoted recognition of mistakes. While watching members of other groups, participants tended to focus on the artifacts they were creating and phenomena that arose, but watching others in their own group, they tended to monitor how individual steps of the recipes were performed, e.g., whether or not there was use of the correct tools and techniques, measuring methods, temperature of water, type of stirring, timing, etc. In

Episode 5.6, I want to highlight how continuously watching both the recipe (instructions) and the other participants within their group promoted use of appropriate materials, in this way avoiding mistakes.

In Episode 5.6, even earlier in Session 1, the boys had just finished preparing their pizza dough, and they had set it aside to let the dough rise. While they waited for their dough to rise, they constructed the yeast-air-balloon water bottles. At the start of this episode, Craig was looking for the correct balloon to use in constructing the yeast-air-balloon activity. He walked back and forth between the group's workspace and the kitchen. Brett had been blowing up the balloon throughout the session, with Craig and KJ watching. William had been getting water to activate the yeast. Notice that the boys' conversation was all about the steps in the procedure – using the right balloon, making sure the water is the right temperature, and checking how much more time the pizza dough needs to rest.

Episode 5.6:
Session 1:
36:50
Craig: [Picks up a balloon on the table] "Which balloon has been blown up?"
Brett and KJ: [Simultaneously. Brett points to the balloon.] "This one."
Brett: [Shaking the balloon that is in his hand]
KJ: "The one that Brett's holding."
William: [Comes in with the measuring cup of water] "It's 122."

37:15
Brett: [Continues to blow up the balloon]
William: [Looks on as Brett blows up the balloon]
KJ and Craig: [Looks at the experiment sheet which is still oriented directly in front of Craig]
Craig: "We…" [Then with emphasis and exaggerated hand motions] "Make sure, [Repeats with increasing volume] MAKE SURE,

[Looking at William and pointing to the experiment directions] it's [referring to the water temperature] between 105 and 115."
William: [Takes the measuring cup and walks out of view of the camera to the kitchen]
Craig: [Continues to read and trails off as he realizes William is gone] "If the water is too hot, add a little hot and cold water and stir until…"
KJ: [Looks at the experiment sheet]
Brett: [Still blowing up the balloon but has now moved closer to KJ]

37:33
Craig: [Looks up] "How much time do we have left?"
KJ: "About two minutes."
Craig: [Looking up says to Brett] "Let it go." [While reaching across the table to squeeze the air out of the balloon]

The conversation in Episode 5.6 shows that KJ has been monitoring Brett's interactions with the balloon. While Craig asks which is the right balloon, KJ's monitoring means he knows which one Brett has been preparing and can direct Craig's attention to it. (The balloon needed to be stretched by repeatedly blowing it up so that the yeast would easily inflate it.) Through his recognition of the appropriate balloon, KJ was in a position to prevent his group from making a mistake that could have impeded their ability to see the target phenomena of the balloon inflating if Brett had not been present to also indicate the correct balloon. Thus, continuous monitoring provided redundancy to prevent mistakes.

In addition, having the right water temperature is important because if it is too cool it will not activate the yeast, and if it is too hot it will kill the yeast. Notice how Craig's continuous monitoring of what William was doing and saying, while Craig was engaging in other activities, helped him catch that the temperature of the water was too hot; as he was able to recall that when William came back to the table he said the water was 122 degrees which was outside of the 105 to 115 degree range suggested as safe by the experiment.

Continuous monitoring of other people within their group helped these boys maintain an ongoing knowledge of the procedures they were enacting and the location and appropriateness of materials. In addition, the abundance of activity, the different roles the boys took on, and the tasks they performed provided each person with firsthand tactile interactions with the materials, artifacts, and resources of which they were able to give an account.

Notice that each of the boys engaged in watching in different ways. Nobody could monitor everything (there was too much going on), especially since monitoring and engaging in the preparation activities were going on at the same time. KJ's watching was most active. He was less engaged in actually setting up the yeast-air balloon, watching as others took more active roles in performing tasks. He was thus best able to answer questions about which materials to use (i.e., correct balloon 36:50) and the amount of time left for the dough to rest (37:15). At the other end of the spectrum, while William was running back and forth to the kitchen, he was not watching what was happening at the table. However, once William returned to the table with the water at the correct temperature his watching of the others was active, like that of KJ. In the middle of the spectrum were Craig and Brett, both of whom were engaging in aspects of experiment setup that gave them opportunities to also watch what was going on (Craig was reading instructions and assembling the parts, and Brett was preparing the balloon).

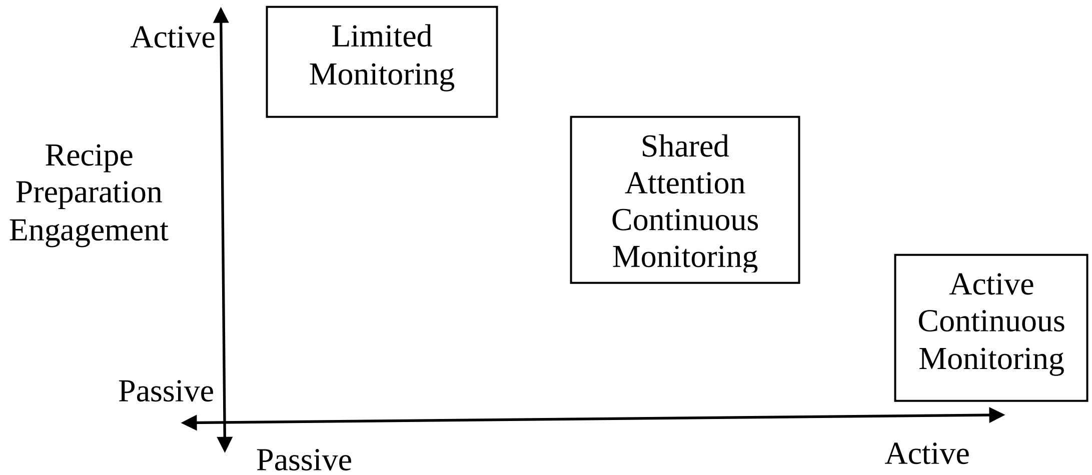

Figure 5.3. Continuous Monitoring During the Recipe Preparation Process

Figure 5.3 shows this graphically. Participants who were less physically involved in the activity were able to monitor more continuously, whereas others who were more physically active had to split their attention, or were unable to continuously monitor. Coordinating all the activity requires that somebody monitor. In this case, the monitoring was distributed across participants. Notice, too, as it will come up in the next chapter, that not all participation in recipe or experiment preparation is equal. Those who regularly have their attention split or are more physically active or distant from the group will not have the same opportunities for experiencing interesting phenomena or knowing how procedures have been performed. For example, when William was running back and forth between the group's workspace and the kitchen, he was not able to engage in continuous monitoring. In the case of this boy’s group, that was not a problem, as throughout the episodes during Session 1 (and later); each participant fluctuated between actively engaging in the preparation process and watching others as they worked. The opportunity for participants to watch parts of the recipe preparation process that they were not actively engaged in allowed them to see phenomena as they arose. Because each had different responsibilities (one focused on the balloon, another on the water), they needed to monitor so they would know when they had to perform their next steps.

It may seem that continuous monitoring was only important for helping the group successfully conduct and complete the cooking and science experiments. However, without completion of activities with minimal errors it was very difficult for the facilitator to help the group compare the artifacts from each variation and to draw conclusions about the role that the ingredients played. In addition, the curiosity that was sparked from participants' continuous monitoring fostered a desire to want to know about the scientific explanation for some of their experiences.

5.2.2.3 Visual Summary

Based on analysis of these episodes, the chart in Figure 5.2 can be enhanced to include Figure 5.4. Figure 5.4 highlights the way that continuous monitoring of others was promoted and what it afforded. The episodes presented show that continuous watching of artifacts and others' work promotes many goals of learning-by-doing learning environments to promote observation of important phenomena, and individual and collective reflection through conversation. Furthermore, these findings show that watching artifacts and other's working during the learning-by-doing activities was fostered by an abundance of activity by each participant and the interdependence of this activity that gave participants opportunities to watch others and their interactions with artifacts.

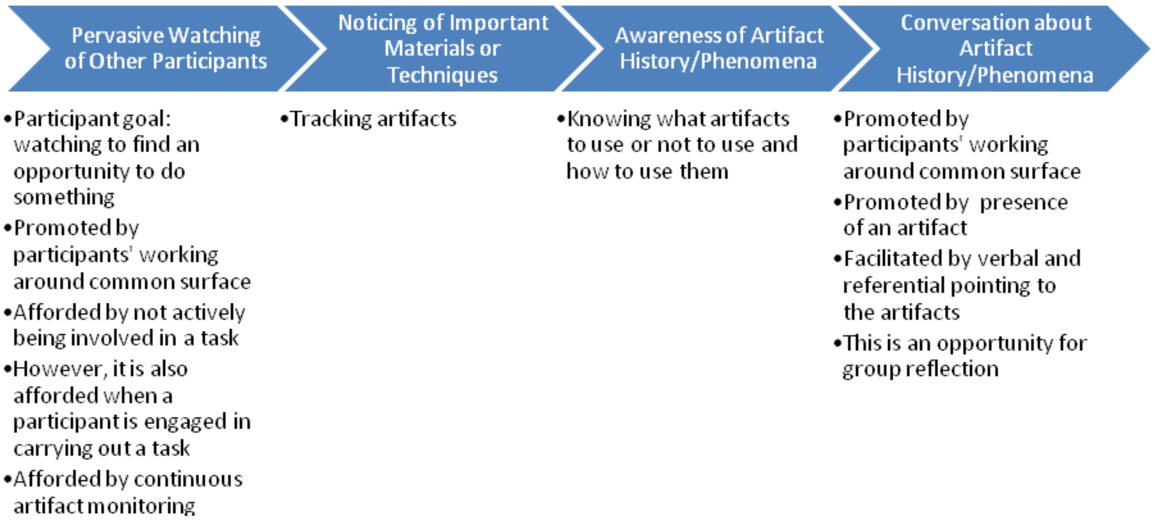

Figure 5.4 Influences and Affordances of Continuous Monitoring of Others

In addition, the continuous visual engagement of the participants promoted observation of important phenomena, piqued participants' interests, promoted location awareness of correct material, and caught mistakes. Furthermore, the continuous visual engagement promoted ongoing cognitive engagement in the recipe preparation process, and of the state of artifacts provided the necessary experiential foundation for participants to reflect individually, as well as collectively, through impromptu conversations I will illustrate in later episodes. Such reflection was important because getting participants to reflect individually can often be challenging in group and hands-on activities. Thus, participants gained a lot of secondhand knowledge and experience through visual engagement.

5.2.3 Auditory (Listening to and Giving Verbal Cues)

The third type of sensory engagement, auditory engagement, augmented both the tactile and the visual engagement:

(1) Hearing verbal cues that signaled other participants' interests and intentions led to attention shifts among less-active participants and piqued their interest.

(2) Hearing verbal cues that signaled the direction of activity led to attention shifts among less-active participants and to them taking on more central roles.

Both of these patterns were pervasive; indeed, participants' interests and what they might decide to do next could shift very quickly after hearing someone else express their interests or what to do next. Indeed, Episode 5.1, presented earlier, provides one example of this. William, upon overhearing Brett and Lisa talk about the water bottle, also became interested in it.

Episode 5.7 illustrates a pattern I found whereby participants' auditory exclamations of interest directed other participants' attention and piqued their interest. In this episode, also during Session 1, Craig was overseeing William's measuring of four teaspoons of yeast, and then sugar, into a cup of warm water. The cup is clear, and at the beginning of this episode, the yeast already is in the water. It is in a mound at the bottom of the cup. The boys are standing around the table watching. As the sugar is dropped in, it sinks to the bottom. For some reason, it draws their attention. Craig says, "Whoa," and then KJ squeals. Everyone's attention is directed to the cup. Apparently, something happened that they were not expecting, and they are all excited. Craig crouches down to look more closely, and everyone else does also. The excitement continues, with different boys noticing different things, discussing what they see, and emitting excited sounds, leading to interest among the others. As they continue watching and William adds more sugar, the yeast begins floating towards the surface, also unexpected. While it is not clear exactly what they are seeing or why they are fascinated, this episode indicates how easy it was for a participant excited by some phenomenon to draw other participants' attention and pique their interest in it. In this case, whatever was happening was exciting to all of them, leading them to both continue to observe and discuss the phenomenon and then make predictions about what might happen next.

Episode 5.7:
Session 1:
39:32
William: [Measuring]
Craig: "Ok we're going to do that 4 times."
William: "Yes, Craig." [With a "leave me alone" tone]
Craig: "So do that twice."[In an authoritative tone] "Then use the tablespoon."
William: [Pours in the 2nd teaspoon]
Craig: [After William finishes pouring in the sugar] "Whoa!"
KJ: [Lets out a noise of excitement and amazement]
Brett: [With his mouth wide open] "Wow."
Craig: [Moves to look at the side view provided by the translucent glass]
All: [Moves back to get a better look at the mound of sugar William poured is sinking to the bottom]
William and Craig: [Come back toward the table]
Brett: [His mouth is still wide open with amazement]
KJ: "Awesome."
William: "That sunk."
Brett: "That was cool."
William: [Recovering, goes back to measuring the sugar] "Two tablespoons of sugar."
William: [Goes back to measuring the sugar]
KJ: [Points his index finger and extending his arm moves it in a circular motion over the top of the glass cup with the yeast and water, and now sugar] "No, no, it turned over."
Brett: "That was weird."
Craig: "That would be one, William."

William: [Pouring in the sugar]
All: [They all look at it again] “Oh!!!”
KJ: “And then the yeast comes up.”
William: [Pouring in the tablespoon and leaning over the table] “This is going to be big.” [He does this with his mouth wide open] “d’Oh.”
KJ Brett, Craig, and Ms. J: [Look on]

What is important to notice here is that the expressions of surprise on seeing the unexpected phenomenon helped the boys know that the phenomenon they were observing was surprising to all of them. That they were all excited seemed to increase their individual excitement at the phenomenon. While the verbal cues did not, by themselves, prepare the boys for anything that came later, they did grab their attention and engage them long enough in observing the solution in the cup to see the yeast begin to move around in the cup.

We know from this episode and also from later discussion that the boys did indeed wonder what caused the yeast to begin to move. Within the session, Christina was talking to the group of girls next to the boys and mentioned that yeast is a live organism. Overhearing this, Brett became very excited, possibly because the fact that yeast is a live organism provided part of an explanation for him of why the yeast would be moving in the water the way he had observed (though that is not actually what made the yeast move). Having seen the yeast move around in unexpected ways, they were now prepared to build an understanding of yeast as an organism.

Episode 5.8 illustrates a pattern I found whereby participants’ indirect speech acts indicated the direction of the activity and subsequently shifted less-active participants into more active roles. In Episode 5.8, we see instances of indirect speech acts directing the activities of other participants: Craig's verbal expression that he needed the yeast to complete the experiment caused KJ and William to begin looking for the yeast.

> Episode 5.8:
> *Session 1:*
> 37:45
> William: [Comes back to the table with the water at the right temperature]
> Craig: "It…" [Voice trails off]
> Craig: "Ok." [With a relieved sound in his voice]
> Craig: "Ok, add, the… Where's the yeast?"
> KJ and Craig: [Look around the table]
> William: [Walks to the other side of the table closer to Craig and KJ, and looks] "Where did you [referring to Craig] put it?"
> Craig: "Yeast." [As if calling a person's name to come, and then pointing to the table off to the side of the girls' group where the yeast jar was sitting]
> William: [Runs and gets it]
> Craig: [Takes the yeast from William] "Ok I'll do it." [He has the measuring spoons in his hands]

While Craig did not ask anyone in particular to help him find the yeast, the boys that heard of his need began searching for it. They had to be continuously monitoring what others were saying and doing to recognize the need to find the yeast.

This episode also illustrates another common pattern of the boys' auditory/verbal engagement. It highlights the idea that the boys often used reading of the recipe (or experiment procedure), questions about where the materials or tools are, and questions about how to carry out some step as ways of positioning others to become more actively involved in the preparation activities. At the same time, others listening and acting on behalf of the speakers were negotiating for themselves firsthand experiences in the recipe or experiment preparation. Overall, giving and attending to verbal cues were used to gain tactile and visual access to the recipe/experiment preparation process. These firsthand and secondhand experiences provided participants with something to reflect upon and connect to later on in the session. Verbal cues helped to focus the boys' attention on what mattered and provided the boys access to firsthand and secondhand visual and tactile cues they might have missed had they not been given.

Note that some verbal cues were intentional and others were non-intentional verbal cues. Participants most often gave non-intentional verbal cues because it was beneficial for the speaker to verbally externalize them (e.g., "Whoa!" in Episode 5.7; and "1/4 tsp" in Episode 5.12). However, the verbal utterances also provided benefits to others as they were able to turn their attention to the activities of the other participants with a more knowledgeable understanding of their interests and intentions. While such verbal cues may have developed into conversations and other interactions between participants and materials, their original intention was not meant as a form of person-to-person communication.

The unintentional nature of these verbal cues could be seen in the following two pieces of evidence: readers sometimes trailed off toward the end of their reading and they often said that they were doing the step. This suggested that they did not intend for the other group members to do activities related to the step.

This stands in stark contrast to intentional verbal cues, uttered with a form that makes it clear that the purpose included directing the hearer's attention (e.g., asking a question, making a request, or issuing a command). There also were times when participants made verbal exclamations that intentionally directed other participants' attention through an explicit expression (e.g., "Look, theirs is getting like ours is." From Episode 5.4).

5.2.4 Overall Sensory Engagement Summary

Ongoing visual engagement as well as watching artifacts and others working during the learning-by-doing activities, promoted observation of important phenomena, piqued curiosity, and promoted both location awareness of correct material and catching of mistakes. Thus, verbal engagement in conjunction with tactile and visual engagement formed sensory engagement that gave participants firsthand and secondhand experiences with phenomena of interest, and the full scope of the activity in general. As you will see, sensory engagement became the backdrop and the conduit, through which participants built patterns of social and cognitive engagement to complete the activity and support the learning.

5.3 Social Engagement

This section focuses on the ways the boys participated in and observed the social structures of the learning environment. I found that the boys' social engagement was characterized by: (1) positioning and activity coordination through recipe-reading and paraphrasing aloud for one another; (2) sharing what they learned from others outside the group, and making decisions together; and (3) making sure that they were doing the preparation process accurately. These three social engagement patterns used the sensory engagement patterns discussed earlier to promote tactile and visual engagement in the activities. They highlighted the ongoing social interactions between participants as they were engaging in the learning-by-doing activities, and in the ways that the participants supported each other in the doing.

5.3.1 Positioning and Activity Coordination through Recipe-Reading

The first pattern of social engagement is positioning and activity coordination through recipe reading and paraphrasing. This was demonstrated in Episode 5.8, when Craig stated that he needed yeast, which prompted William and KJ to begin looking and hunting for the yeast. As previously discussed in the sensory engagement, the boys' reading the recipe/experiment aloud served as a verbal cue for others to pay attention, cued the boys with opportunities to secure ingredients and utensils, and allowed them to position themselves as firsthand participants in the activity. Positioning and activity coordination through recipe reading were fostered by verbal cues and continuous monitoring of artifacts and others as they worked.

Patterns of recipe reading as a means of activity coordination could be intentional or non-intentional. Non-intentional activity coordination happened when a boy was reading the recipe instructions aloud to himself, resulting in others doing what was needed to prepare for the next steps. Intentional activity coordination was a reading of a recipe or procedure for others or when one or more of the boys asked what the next step in the recipe/experiment was in order to position himself to participate in the preparation activity. A participant could position himself to participate in the activity by making himself aware of a recipe step and preparing himself for it (e.g., by holding a needed utensil or ingredient in his hands). Participants could also keep others from participating by not allowing access to a recipe and restricting others access to utensils or ingredients.

5.3.1.1. Non-intentional Positioning and Activity Coordination through Recipe/Experiment Reading

Episode 5.9, which again took place during the first session of the KSI program, illustrates this pattern. It began with a single participant, Craig, reading the recipe aloud, perhaps to mentally coordinate his own activities, and other participants listening and moving to act on what they heard. Craig read the recipe aloud while the other group members listened, and then began gathering the ingredients with him:

> Episode 5.9:
> *Session 1:*
> 34:43
> Craig: [Comes back to the table with the funnel and the experiment sheet. With the experiment sheet in hand he begins to read] "Ok, the first thing we do is get one cup…"
> William: [Grabs the water bottle]
> Craig: [Repeats] "One cup."
> William: [Picks up the glass tumbler]
> Craig: [Repeats himself again with a little more force and disgust while picking up the liquid measuring cup and handing it to William] "One cup."
> Brett: "Oh!" [With a surprised look on his face then starts laughing]
> William: [Immediately looks at the side of the liquid measuring cup]

Notice that reading the recipe aloud both provided the other participants with opportunities to participate and also positioned the recipe reader as knowledgeable. In this case, William, who was unfamiliar with cooking and measuring terminology needed correcting as he moved to involve himself. Craig corrected William's selection of the container with which to measure "one cup" of water. William's lack of prior cooking experience and dearth of understanding the nuances of cooking terminology (i.e., cups) often resulted in his actions being corrected by the other group members.

5.3.1.2. Intentional Positioning and Activity Coordination through Recipe/Experiment Reading

In other patterns of participant positioning and activity coordination, each individual in the group began to act as the recipe reader to intentionally position himself or herself to take on first-hand experiences preparing the recipe/experiment. While I call this coordinated, it does not look like the coordination of adult groups, rather participants vie for the chance to have a turn, asking what the next step is as they see the current step nearing completion and they attempt to secure the ingredient, tool, or resource needed to complete the next step, or jumping in to read the next step.

Episode 5.10 highlights this pattern. The episode started as the group was completing one of the steps, indicated by Craig's measuring out the yeast, and William's asking, "What do we do now?" (38:56). William then asked this question a second time (39:32); however, this time William positioned himself so that he could read the experiment directions aloud. Craig then jumped in and pointed to the correct step, and read aloud "Yeast and Sugar", then "Stir until dissolved" (39:32). After Craig read this instruction, he sought out the sugar, while William began to look through the measuring spoons, and Brett looked for a spoon:

Episode 5.10:
Session 1: Yeast-Air Balloon Experiment
38:56
KJ: [Bent over the table looks into the cup] "It's going to pile up like an island."
Craig: [Still measuring the yeast and pouring it into the cup of water. He then places the ring of measuring spoons down on the table and looks for the ¼ spoon] "1/4".
William: [At the same time that Craig is measuring, William comes back to the table saying] "What do we do now?"

39:09
KJ: [Looking over at Craig trying to find the ¼ tsp measuring spoon] "You can use 1/8th two times."
Craig: "Good point."
KJ: [As Craig picks up the measuring spoons] "I see the ¼."
Craig: "I found the ¼." [As he's scooping out the yeast]

39:32
William: [Looks down at the experiment after Craig finishes pouring the last bit of yeast in] "Now what's next?" [Then begins reading as he moves his body closer to the table] (Put the text that he reads here) [Then he hesitates]
Craig: [Bending down over the experiment with emphasis and pointing] "Yeast! And sugar!" [Lowering his tone to a reading tone, he says] "Stir until dissolved." [Then he summarizes] "So the sugar. Sugar. One. Two, tablespoons of sugar."
Kris: [A boy from another group approaches the table as Craig finishes saying sugar] "Sugar, we need the sugar."
Craig: "No we're using it right now."
Kris: [Says quietly] "Can I…?" [Voice trails off and he just stands there waiting, blocking the view of the camera to the work that is going on at the table]
William: [Meanwhile looks through the ring of measuring spoons] "Two tablespoons of this."
KJ and Brett: "Yes."
Facilitator Oriana: [Walks up beside Brett]
Brett: [To Oriana] "What spoon are we going to use?"
Oriana: [Looks around the table] "I'll go get you one."
Brett: "I get to stir."
Craig: [Looking at Oriana] "OK." [Then, looking down at the experiment announces to his group members] "I get to do step 4."

This pattern of materials acquisition highlights the inherent interdependence of materials, activity, and participants created by such materials acquisition: Craig had the ingredient to be measured (sugar), William had the tool (spoon) for measuring the sugar, and Brett had the spoon for stirring the mixture of sugar, water, and yeast. In addition, since Brett and KJ watched and listened to the interactions between Craig and William, they were able to answer William's question about the measurement size and the amount to be measured.

In subsequent episodes, I found that the "Now what's next?" phrase became a common prompt for the boys in this group to read and/or summarize aloud the next step in the recipe or experiment. Reading recipe/experiment procedures aloud provided opportunities for the reader to make sure the rest of the group was following the preparation process, while the reader positioned himself to be a primary participant by making declarations about what part of the preparation he was going to perform. Additionally, when they were trying to do something, they spoke it aloud. All these recipe-reading procedures became affordances for experiencing and participating in the recipe/experiment preparation process.

One more pattern of intentional activity coordination arose. A participant would refuse to read a recipe aloud and keep it from others so as to be in control for longer. For example, in Episode 5.11, which immediately followed the interaction in Episode 5.9, notice that Craig switched to reading the experiment procedure to himself instead of reading the experiment aloud this time to circumvent others from gathering the materials and completing the next step. In fact, he had not liked that others had begun collecting ingredients; he had wanted to do it himself.

Episode 5.11:
Session 1:
34:48
Craig: [Looking down at the experiment and reading silently]
Craig: "I get to do this part." [And tries to grab the measuring cup from Andrew]
William: [Pulls the measuring cup back toward himself and walks toward the kitchen]

Craig: [Goes as well. Then almost immediately after walking out of sight of the camera, he returns to the table with the funnel in his hand]

Reading the recipe/experiment to himself gave Craig privileged access to the doing of the activity by not revealing the next instruction, or the tools/utensils needed to complete the task. Having realized that he unintentionally allowed others to coordinate with him, Craig was trying to use the recipe/experiment both to increase his knowledge of the preparation process and to ensure that he was the one with the firsthand experiences to complete the instruction. Basically, Craig was positioning himself to have "his" turn.

In summary, recipe-reading, whether intentional or unintentional, created three patterns of positioning for participants: (1) When a participant heard the ingredient, resource, material, or artifact mentioned by another participant as he read the recipe, or requested a particular ingredient, other participants eagerly engaged to acquire the ingredient; (2) A participant sometimes adopted the practice of reading the recipe silently to himself as a way to position himself to monopolize the activity by getting the materials and measuring them himself; and (3) Participants adopted the practices of asking what the next step was, reading the recipe to themselves, and making verbal declarations about what parts they were doing.

5.3.1.3 Participant Positioning and Activity Coordination through Essential Material Acquisition

In the positioning and activity coordination via recipe-reading patterns discussed in the two previous subsections, possession of essential materials became a major tool with which participants positioned themselves in the coordination and execution of the recipe/experiment preparation process. In this way, reading the recipe emerged as a social interaction that evolved the ways participants worked together to coordinate and conduct the activity. In particular, who read the recipe, how the recipe was read, and who was able to obtain the necessary materials for executing the recipe step, in addition to the interdependence between ingredients, allowed participants to position themselves to have firsthand experiences in the recipe-preparation process. Access to materials was essential when their use was necessary for the completion of the activity. Participants who were able to obtain essential materials were able to use their possession as leverage for a position of greater active engagement in the recipe-preparation process.

Episode 5.8, which I discussed earlier, provides a great example of how materials were sought out. Recall that in this episode, Craig asked, “Where’s the yeast?”, and William and KJ began looking around the table, until William finally ran to find and bring the yeast back to the table. Craig, with measuring spoons in hand, immediately took the yeast away from William, saying “OK, I’ll do it.” This episode serves as evidence that acquisition and retention of materials gave the acquiring party power to execute the recipe/experiment step.

Now recall that by Episodes 5.9 and 5.11, the participants had learned this lesson, and each had retained possession of a different tool/material/resource needed to complete the yeast-air balloon experiment. Episode 5.9 highlights the various ingredients that the group members were in possession of, or took possession of: (1) Craig was holding the funnel and the printed experiment; (2) William grabbed the liquid measuring cup; and (3) Brett maintained possession of the balloon.

Episode 5.11 highlights the ways that the participants used these ingredients to position themselves in the preparation of the yeast-air balloon water bottle. Craig positioned himself as the reader of the experiment's instructions, and maintained a firm grip on the experiment paper. In addition, recall that Craig read the recipe instruction to himself, and then forcibly tried to obtain the liquid measuring cup from William so that he could complete the step on his own. However, William retained his grip on the liquid measuring cup, and once he found out that it needed to be filled with water, he walked to the kitchen to get the water needed to activate the yeast. Meanwhile, Brett retained possession of the balloon he had been blowing up so he would have the opportunity to put it on the water bottle to complete the assemblage of the yeast-air balloon experiment artifact.

While the positioning in these three episodes borders on the extreme (with the struggle to obtain an essential material/tool), it was not uncommon for participants to vie for an opportunity to have their turn to measure, stir, knead, or otherwise participate. Moreover, these episodes highlight the pervasive nature of how essential materials were sought out, acquired, and retained for use by the participant who acquired them, as a form of positioning.

In addition, the interdependent nature of the acquired materials served to further coordinate participants' activities, due to the vigilance required to use the materials as a means to strengthen the participant's position in the activity. Thus, at any given time participants were continuously monitoring multiple tasks, and several material interactions occurred simultaneously (e.g., William's getting the right temperature water, Craig's measuring the yeast, and Brett's blowing up the balloon). This simultaneous material acquisition and retention by different group members created the necessity for rapid verbal exchanges and non-verbal material interactions that characterized this group's interactions. Because of the vying for turn taking in this group, sensing of verbal cues, discussed in an earlier section, was essential if participants were to position themselves to participate.

In summary, the interdependence of steps and materials encouraged participants to be mindful as the recipe/experiment procedures were read by others, to also read the recipe themselves, and to ask each other about what was next in the recipe. Recipe reading was used to govern patterns of material acquisition and who was in possession of those materials. When multiple people had possession of the materials needed to complete a single task, there was a need for social interactions between participants that prompted dialogue. This pattern of social interaction, activity coordination, and dialogue was a persistent feature of the boys' interactions, as they prepared recipes and carried out investigations throughout KSI.

5.3.2 Patterns of Sharing and Collaborative Decision-Making

In contrast to when participants were vying for their turn in preparing recipes, at times when they needed to make decisions or figure out how to do something, the boys were more collaborative. In Episode 5.12, for example, the boys could not find a ¼ teaspoon measuring spoon. They did have 1/8 teaspoon measure available, and KJ, who had only been watching up to then, had the opportunity to offer a practical and mathematical-based solution to the missing measuring spoon, thus becoming more actively engaged. Such helpful advice allowed the activity to proceed without too much wasted time.

Episode 5.12:
Session 1:
38:00
Craig: [Looking at the experiment, then to the measuring spoons in his hands] “Two and one fourth.”
William and KJ: [Looking on at the measuring spoons]
William: “It’s half a tablespoon.”
Craig: “No, it’s one teaspoon.”

38:25
Craig: “Is this yeast?” [Picking up the jar of yeast]
KJ: “It’s bread machine yeast, Craig.”
Craig: [With a little bit of sass] “It's supposed to be dry active yeast!” [While he measures the first teaspoon of yeast, says anxiously] “Where do I put it?”
William: “Right here,” [Pointing to the liquid measuring cup]
Craig: “No, you’re supposed to put that [water in the liquid measuring cup] in the cup [clear glass].”
KJ: [Picks up the cup, then places it back down on the table in front of him]
William: [Walks around toward KJ with the liquid measuring cup and the thermometer in his hand. Then he placed the cup on the table next to KJ] “It’s about 110 degrees.”

38:56
KJ: [Bent over the table looks into the cup] “It's going to pile up like an island.”
Craig: [Still measuring the yeast and pouring it into the cup of water. He then places the ring of measuring spoons down on the table and looks for the ¼ spoon] “1/4.”
William: [At the same time that Craig is measuring, William comes back to the table saying] “What do we do now?”

39:09
KJ: [Looking over at Craig trying to find the ¼ tsp measuring spoon] “You can use $1/8^{th}$ two times.”
Craig: “Good point.”
KJ: [As Craig picks up the measuring spoons] “I see the ¼.”
Craig: “I found the ¼.” [As he’s scooping out the yeast]

This episode highlights the ways that continuous monitoring of others and of artifacts, fostered opportunities for giving and receiving advice. In this case allowing KJ, who was not as active a participant but was actively monitoring, to have a turn contributing to the group.

Another type of situation where collaboration was valued was when one boy knew something that the others did not know. For example, sometimes a participant would talk to a facilitator and learn something new and useful. When that happened, the boy who interacted with the facilitator eagerly shared what he'd learned from the facilitator with the rest of the group. In some instances, this sharing created a need for the group to decide between several options for how they should proceed. Episode 5.13 is an example of this pattern. Episode 5.13 happened during Session 5. The boys decided to make cookies with yeast because they wondered if yeast could be used in cookies and if so what might happen. But, to adapt the cookie recipe, which used baking soda and baking powder, to use yeast, they realized they needed to change the procedure. They knew that baking soda and baking powder are activated by water and heat. However, they also know that yeast needs to be activated (awakened) by warm water before being added to the recipe. In addition, they did not know if the sugar should be added to the yeast or creamed with the butter. So they did not think that they could simply substitute the yeast in the recipe. Craig wondered about the procedure they should use to carry the yeast substitution out. He had a conversation with Christina, the facilitator, about the different options for adapting the cookie recipe to accommodate the water needed to activate the yeast. Based on this conversation, he returned to his group to share with his group members the need to activate the yeast in its own bowl, and to decide along with them what bowl to place the sugar in. In Episode 5.13, you see him sharing the information and to focus his group on making a decision on where to put the sugar. Craig positions himself as expert, making suggestions to be considered and pushing for an answer.

Episode 5.13:
Session 5
22:53
Craig: [Goes over to his group and shares with his group the conversation he had with Christina]: "So we need three bowls, one for the wet ingredients, one for the dry ingredients, and one for the yeast and the water. Should we put the yeast in a separate bowl from the wet and dry ingredients?"
Brett: [Walks away as Craig begins talking]
KJ: [Comes back to the table]
William: [Focused on another ingredient, begins talking over him]
Craig: "William, listen! We have to make a decision about what to do."

23:13
Craig: "Yeast and water, or yeast, water, and sugar?"
William: [Totally distracted by something in a container, interrupts Craig again while Craig is talking] "This is the coolest thing ever."
Brett: [At the same time as William's outburst, responds to Craig] "Yeast and water." [Inaudible over William talking, which shifts the group's attention to William]

23:21
Craig: [Holding his hands up to his ears in a sign of frustration to drown out what William is saying] "Guys we need to figure this out now."

23:39
Craig: "We have to decide if we are going to put the sugar with the yeast and water, or if we are going to put the yeast with the dry ingredients. She said we have to have three bowls: one bowl for the dry, one for the wet, and one for the yeast and water."

23:45
Brett: "I think just the water and the yeast."
Craig: "I think the water, the yeast, and the sugar because the sugar needs the water to wake it up. I mean the yeast needs the water to wake it up and then the yeast eats the sugar."
KJ: [Inaudible exchange between Craig, William, and KJ. KJ raises his hands above his head enthusiastically. He later repeats this gesture during the ending discussion, which denotes gas escaping]
KJ: "So we put the sugar with the dry stuff for the dough."

This pattern of sharing what they learned shows three aspects of their social engagement. First, it allowed William, KJ, and Brett to have secondhand access to information they were not initially present to hear; Second, it showed that communication between the boys was welcomed and valued, at least after they were all focused on the same thing. Third, it promoted cognitive engagement with the kitchen science. While Craig pulled the group together to make a decision, they all grappled with their understanding of how yeast works as they were trying to decide what they should do with the yeast and the sugar in the cookie recipe. While in the previous examples, it looked like this group's culture was one of vying and competition, they also valued collective decision making (when they could be pushed to all focus together). The monitoring they engaged in allowed them to position themselves for turn taking, all were prepared to participate (i.e., know enough) when discussions needed to be had.

5.3.3 Catching and Correcting Mistakes and Making Sure They Were Doing the Right Thing

The continuous monitoring the boys did to position themselves for turn taking was also useful for quality control because they were aware of steps that came next, they were also aware of the amounts of ingredients to use, the correct temperature of the water, and other specifics important for accurate preparation. They developed practices for catching and correcting mistakes and mistake avoidance.

In the previously discussed Episodes 5.12 and 5.9, I highlighted that continuous watching often led to participants' correcting one another within the group. In Episode 5.9, Craig caught and corrected William's lack of knowledge about use of utensils, which could have resulted in using an inappropriate cup to measure the water. In Episode 5.12, Craig reread the recipe to William several times to help him understand that the temperature of the water needed to be within a specified range. In both of these situations, Craig's correction and prevention of mistakes arose out of the group's pattern of recipe-reading and continuous monitoring of the preparation process.

At other times, they seemed to be intentionally monitoring for quality control. For example, in Episodes 5.14, William was preparing to measure the sugar. He was supposed to measure out two tablespoons and had a teaspoon in his hand. Kris, from another group, was waiting for the sugar with a tablespoon in his hand. William measured out and put in the first amount of sugar, and had asked how many spoonfuls were needed, KJ noticed that the spoon in Kris' hand and the one in William's were different sizes. He corrected William.

Episode 5.14:
Session 1:
39:32
William: [After measuring out the sugar] "One," [Then he pours it into the glass with the yeast and water]
KJ and Brett: [Look into the glass cup with the yeast and water as the sugar is being added]
William: "Ok two of them. How many?"
Kris: [At the same time, Kris comes back to the table blocking the camera again and stands between KJ and William with his measuring spoon ready to measure his sugar that they denied him earlier]
KJ: [His attention shifts from the glass toward the direction of Kris and William, with his hand stretched toward them, and especially toward Kris' hand that is holding out the measuring spoon, but Kris' body obscures the view. Then he moves Kris's hand out of the way and launches in toward William who's measuring the next amount of sugar] "No, no. That's a teaspoon."
Kris: "Two tablespoons." [With emphasis, but not as aggressive as the other members of the group]
William: [Steps back]
Kris: [Measures his sugar]
KJ: [Makes eye contact with William] "Tablespoon."

Craig: [Focused on the activities of the next step, holds the funnel and a liquid measuring cup] "I get to do the part of step 4…" [He is cut off by KJ]
KJ: [Asking Ms. J, who happened to be walking by and looking on at what is going on at the tables] "How many teaspoons are in a tablespoon?"
Ms. J: [Leans in and says something inaudible]
Craig: [Inaudible]
Ms. J: [Looks around]
KJ: "OK, so use two of those."
Craig: "No, no, there are tablespoons on there."
KJ and Craig: [Look through the ring of measuring spoons]
KJ: "I know he was using teaspoons."
William: "Ah!"

KJ could catch the mistake because he was monitoring the activity and knew the difference between teaspoon and tablespoon measures. Ironically, in most of the "correcting" episodes referenced in this chapter, William was the one being corrected. However, in Episode 5.15, William, having learned from all his mistakes and near mistakes, attempted to use his knowledge of the pizza preparation to correct the girls' group adjacent to his. Both groups were making pizza during Session 8, and the girls group was rolling out their dough while his group's dough was still resting.

Episode 5.15:
Session 8:
52:44
William: [To the girls who are fighting over whether they should make one or two pizzas] "Did you let your dough rest?"
Girls: "We didn't need to let our dough rest because we are using baking soda and baking powder."

William's awareness and interest in alerting the girls to a potential mistake suggested that he was continuously monitoring the activities of not just his own group, but those of the adjacent girls' group as well. Moreover, attending to and correcting mistakes were applications of the pattern of interactions he had experienced within his own group.

These episodes, Episodes 5.6, 5.9, 5.14, and 5.15, provide evidence of two patterns of mistake correction. Episodes 5.6 and 5.9 highlight mistake correction by one's own group members. Episode 5.15 highlights the noticing of a potential mistake across adjacently-located groups. In this situation, a visitor to a group became engaged in monitoring and helped catch mistakes.

5.3.4 Social Engagement Summary

Social engagement in KSI activities took these forms: (1) coordination of activities and positioning of oneself to have firsthand experiences through recipe-reading and acquisition of essential materials; (2) participants' sharing what they'd learned with one another, and working together to find solutions to problems; and (3) closely monitoring one another's activities to ensure that they were done correctly. These three activities were essential for their later reflection and other cognitive engagement.

5.4 Cognitive Engagement

Up to this point, I have been highlighting and discussing the sensory and social engagement patterns that provide support for cognitive engagement. I've found that one of the major cognitive benefits of sensory and social engagement is that it fostered monitoring the changing state of the recipe artifacts and the preparation process, which are critical for reflecting on and reasoning about cooking and science phenomena. In this section, I focus on the opportunities for cognitive engagement promoted by sensory and social engagement. In particular, I pay attention to the role monitoring the changing state of the recipe-preparation process played in helping participants reflect individually and as a group.

While patterns of sensory and social engagement were generally drawn directly from small-group interactions among participants, patterns of cognitive engagement were often drawn indirectly from small-group and big-group interactions. Since we ca not directly see participants' cognitive engagement, I infer it from their talk, writing, drawing, and other interactions with each other while reflecting.

In the following sections, I will discuss the ways: (1) sensory engagement patterns I observed led to participants' reflection-in-action; (2) social engagement patterns led to participants' reflection-on-actions; (3) sensory and social engagement patterns led to reflection that supported participants' engagement in KSI activities; and (4) connections between these three patterns of reflection and the resultant learning by the participants.

5.4.1 Sensory Engagement Leading to Reflection-in-Action

Reflection-in-action is a term coined by Schon (1987), which refers to reflection done while "doing" or thinking about what one is doing while doing it. Such thinking on one's feet allows recognition of interesting aspects of the activity and the ways that one is engaging as activities are carried out. It is essential for catching mistakes before they happen and improvising to be able to perform under-defined parts of a task. During learning by doing activities, this type of reflection can often be difficult. It is often easier and more fun for participants to remain physically engaged in an activity than to extract themselves from the activity to think about it (Chinn & Malhotra, 2001; Blumenfeld et al., 1991, Engle, 2011). However, I found that the boys' sensory engagement with artifacts and others gave them reasons for stopping to reflect in the moment.

Consider again Episode 5.5. Recall Brett and Craig were preparing pizza dough as KJ and William looked on. While KJ and William were observing the recipe-preparation process, they noticed that the group of girls that was working beside them was tasting dough. This prompted them to want to taste their dough and to describe it.

Episode 5.5:
Session 1:
30:00
Girls at the adjacent table: [The girls from the group next to the boys begin tasting their dough since it was all over their hands.]
One of the boys from the group says "You're tasting it?!"
KJ: [announces, with his hands covered in dough] "I'm licking my fingers." [while the others pinch off pieces of the dough] "I'm going to describe what it tastes like."
KJ and William [taste the dough]
Brett: "I'm not tasting it."
William: "Chewy but" [then stops talking and looks at KJ with a whimsical look]
KJ: "Chewy but like (pause) chewy!" [while looking off and with a thought-engrossed look on his face]
William: "Chewy but a little bit. A little bit. It has a taste of salt." [He says this while pointing at KJ in reasoning like stance.]

Seeing the girls tasting their dough seemed to be surprising to the boys. Recognizing the opportunity to taste their dough initiated the boys' reflection-in-action as evidenced by KJ who explicitly stated that he was going to describe what the dough tastes like. KJ may have been reminded of the five senses chart provided at the beginning of the activity to help them record observations. The chart prompted them to use their five senses with pictures of each of the five senses and space below to record their observations. However, as stated before, this episode fits in the pattern of continuous monitoring of others that results in recognition of new ways of participating in the activity. Thus, tasting the dough and recording observations about the characteristics of the dough became a way that KJ and William could participate in the activities and for them to initiate reflection on their own terms. Thus, the continuous visual monitoring allowed KJ and William to reflect-in-action on the pizza dough their group was preparing through making observations about the taste, texture, and mouth-feel of the dough.

The next two episodes show the continued influence of the initial visual surprise of the girls tasting their dough. Once cognitively engaged in the task of describing and recording the taste and texture of the pizza dough, KJ remained occupied with this task. In Episode 5.16, minutes later, we see KJ reminding William, who had just finished washing the dough off of his hands, to record observations. However, William was now focused on the next activity- preparing the yeast air-balloon experiment.

Episode 5.16:
Session 1:
31:35
William: [walks back to the table as KJ and Ben are walking away to wash their hands]
KJ and Ben: [Their hands are covered with dough.]
KJ: [says to William from across the table] "Write down what you said: 'Chewy but floury.'" [He says this as he points down to the five senses chart.]
William: [is moving the spoon around in the big green mixing bowl looking like he's paying attention to someone else, and says at the same time or immediately after KJ is finished talking] "Tammy."

This episode highlights reflection on the experiment process. In particular, it represents reflection on the need to make observations as a form of data collection and the need to record that data. This reflection would have never happened had it not been for the boys' consistent monitoring of the artifacts and participants in their own group, and the adjacent girls' group. Moreover, their sensory engagement fostered immediate reflection on the dough artifact as they were in the process of preparing it. Stopping to make observations and remembering to record them is a vital part of data collection while running experiments that is often forgotten when participants are in the midst of these activities. Thus, for participants to draw out rules of thumb it is important for them to make these kinds of observations so that they can relate the taste and texture to particular measurements of ingredients.

The same pattern is seen in Episode 5.2. Recall Episode 5.2, where the boys were discussing the history of the foam height in the yeast-air-balloon water bottle. The discussion the boys were having in this episode is an example of how continuous monitoring of artifacts allows participants to observe the visually-changing aspects of the artifact. Continuous monitoring of artifacts allowed them to notice a dramatic change in the foam the yeast creates, which piqued their interest and led to discussion about the history of the height of the foam. The important part about noticing the visually-changing aspects of this artifact overtime is that participants had the opportunity to notice that yeast works slowly and thus needs time to start producing carbon dioxide and does so for a long period of time. This observation is important because later participants observe that baking powder works immediately when activated and only produces air for a short period of time. This was an important observation for the group to make because it helped them to later make changes to the recipe procedure for the cookies when they substituted out the baking powder for yeast.

In addition, this reflection on the height of the foam made them curious about what was happening in the water bottle and prepared them to make connections between what they were seeing in the water bottles and the science explanation they heard in the big-group discussion at the end of this session about how yeast works over time to eat/digest sugar and produce carbon dioxide. Thus, the boys' reflection-in-action on the visually-changing aspects of the foam height in the yeast-air balloon artifact was supported by their constant monitoring of artifacts over time.

5.4.2 Social Engagement Patterns Leading to Reflection-on-Action

The social engagement patterns I observed the boys engaging in during the recipe-preparation process were also used by the boys to collaboratively reflect on their experiences afterwards. Schon (1987) refers to reflection-on-action as a type of post-activity reflection that shifts reflection into the focus of participants' attention and engagement. Reflection-on-action helps the learner take a closer look at what they had done somewhat unconsciously. Reflection-on-action can often take the form of peers critiquing each other or a teacher/facilitator asking the participants questions about what they have done (c). This is the type of reflection that is most encouraged in hands-on learning because it is often hard to get participants to reflect in the moment.

To facilitate participant reflection-on-action during KSI small-group activities, we prepared reflection questions in advance to prompt them to notice particular features of the artifacts they created, in addition to providing them free form places to reflect. Participants reflected on what they'd done through writing stories and explanations about their experiences as well as rules of thumb for others to be aware of when they use the ingredient the next time.

What is interesting is that the ways that the boys engaged in reflection-on-action mirrored the patterns of social engagement they used during the recipe-preparation process. Recall that social engagement patterns were beneficial in helping participants: (1) to position themselves and to coordinate the activities of the group; (2) to develop a culture of sharing and collaborative decision-making; and (3) to correct and prevent mistakes. I observed the boys continuously monitoring each other as one of them was recording his thoughts about the group's experiences and updating observations they had made previously. In addition, I saw the boys checking, correcting, and adding to the thoughts their peers had written.

In this section, I highlight the ways that participants used the social engagement practices they developed to help them reflect. In particular, the group's practices of monitoring each other and checking to make sure no mistakes had been made were adopted by the boys when they engaged in reflection activities as well. Episode 5.17 highlights two examples of this pattern of checking and the process by which the boys reflected on their cooking experiences and created written artifacts.

In Episode 5.17, the boys just finished preparing their revised pizza recipe and were waiting for the pizzas to come out of the oven. Thus, they were engaged in cleaning up their area, making predictions about how their pizzas would turn out, and reflecting on the preparation process through written artifacts (see Figure 5.5 for the observational notes they recorded and Figure 5.6 for the notes they made on the recipe planning page).

Before presenting the transcript for Episode 5.17, I present the content of the artifacts that participants created as they reflected because the transcript highlights the process by which these artifacts were created. Figure 5.5 depicts the text written by the boys on a blank poster labeled with the heading “Session 5- Group 1”. On the observational poster, notice that the boys were writing about not only what they saw while preparing the recipe, but also the connections they were making to scientific phenomena experienced and explanations they’d heard. In particular, they were reflecting on the scientific process by which the yeast is activated by the water and eats the sugar (i.e., “Sugar got devoured by the yeast.”). In addition, they described the change in the state of the pizza dough by initially describing the dough as being similar to cake batter, and then it turned into the dough they saw the first time they made the pizza dough. From these descriptions it is clear that they were making connections and comparisons not only to specific observations they previously made of the dough during the preparation process, but also to their previous experiences with cake batter and making dough, and previous explanations of what they had observed.

Session 5 **–** Group 1

Sugar got devoured by the yeast
When the yeast hit the water it spread out
The oil stayed in clumps
The flour stays in clumps until stirs well to mixture
It looks like the cake batter
Turns back to dough from the first time we made it
Stays same thickness while resting. Sshhhhhhhhhhhhhh
It turned much thicker
1 inch wide/when we put it in the oven
Unknown but thicker
less sticky (held itself together a lot better)
heavy
smooth

Figure 5.5: Group 1 – Session 5 – Observational Poster

Figure 5.6 is an excerpt from the “First Retry Day Reflection Sheet: Pizza.” The First Retry Day Reflection Sheet was a multi-page packet that included five planning pages that asked the participants to think about their goals for changing their selected recipe, the specific ingredient and procedure changes they would make, and the science evidence to justify their changes.

Notice the prompts we used in the reflection sheet to get them to reflect. We specifically asked them to think about their previous experiences making pizza and the changes they made to the recipe. These prompts were specifically selected to help the participants make sense of their experiences over the course of the five KSI sessions they had participated in up to that point. In making the pizza on Retry Day, the boys wanted to make their pizza into a thick crust pizza. Believing that more yeast would make the pizza crust taller/higher, they decided to add more yeast. This was demonstrated by their answers to the prompts on this planning page. Thus, the questions on the sheet prompted them to think back to their original goals for changing the recipe and to make predictions about how the pizza was going to come out.

[Excerpt from the "First Retry Day Reflection Sheet: Pizza"]

Question 4: Look at your dough and compare to the original recipe dough that you made during Session One (and that Ms. J. has prepared). What difference do you notice between your dough and the original recipe dough? Do you think these differences were caused by the changes you made? Why or why not?

Question 4 Response: "Because of our changes in the recipe it is taller than the orig. recipe"

Question 5: Based on the difference in Question 3, what do you think the differences will be between your pizza and the original recipe pizza once it is done. Why?

Question 5 Response: "The crust will be taller than the first because we made the crust taller and there's more yeast and sugar."

Figure 5.6: First Retry Day Reflection Sheet: Pizza

Now that we have discussed the content of the participants' reflection, I want to present the process by which the participants engaged in to produce these reflective artifacts by looking at the transcript of this process. As you read the transcript notice the two instances of "checking" and how they form the process by which this group reflects: (1) when Brett was checking over what Craig had written on the group's observations poster (Figure 5.5), and (2) second, when Craig and William were checking over what KJ had written on the planning sheets (Figure 5.6).

Episode 5.17:
Session 5:
1:03:08

[After cleaning up their space, the boys look at their papers. (Planning and results sheets at their table. Refer to Figure 5.6 for text of artifact)]

1:03:45

Craig: [gets up and jots notes down on the poster wall, see Figure 5.5]

Brett: [joins Craig at the poster wall and stands behind Craig as he writes on their observation poster, Figure 5.5]

KJ: [He stays at the table, writing on the planning sheets (see Figure 5.6). He writes that they ‘forgot to measure the width”.]

Craig: [hangs the pen on the poster wall and then walks back to the table]

Brett: [looks at what Craig has written and walks toward the poster (reference Figure 5.5) and gets the pen and writes something]

1:04:16

[Craig and William look through the planning and results papers and write down something on one of the pieces of papers on the table. They answered questions 4 and 5 on the “First Retry Day Reflection Sheet: Pizza” (see Figure 5.6)]

This episode demonstrates the ways that the boys individually and collectively recorded their observations by watching others while they wrote, as well as checked, corrected, and added to what others had written. It was important that these participants checked over what others had written because it showed that they knew, and were confident enough to correct, what the mistake was or to fill in gaps in what the other participants had written. It was particularly remarkable that they did this on their own because it showed they were very interested in the activity and knowing what other participants thought about the experiences. While there were many reasons the participants might have developed this practice (e.g., personal work ethic, school culture, etc.), it appeared this was consistent with the social engagement patterns of continuously monitoring and checking that they had been engaged in throughout the recipe-preparation process.

One of the most interesting parts about this episode was how little the participants talked to each other as they were reflecting. This suggests that as individuals, their prior sensory and social engagement in the activity provided them with sufficient experiences on which to reflect. In addition, this episode suggests that each person was reflecting individually and reviewing what the other participants had written. It seems that this was possible only because participants had so many shared experiences during the preparation process and paid such close attention to the changes the recipe underwent and what others were doing throughout the activity.

5.4.3 Cognitive Engagement Leading to the Uptake of KSI Engagement and Learning Goals

The episodes in Sections 5.4.1 and 5.4.2 highlighted emergent opportunities for reflection created through sensory and social engagement. This section highlights how these emergent patterns of reflection fostered the goals for reflection originally intended by the KSI design.

Our goal in designing KSI was to provide opportunities for participants to engage in investigative practices and reflection on their own volition. The previously highlighted sensory and social engagement patterns illustrate the ways that participants willingly and voluntarily engaged in the KSI activities. In addition, these patterns highlighted ways in which opportunities for cognitive engagement resulting in the achievement of our design goals were afforded in unanticipated ways.

Our designed goals for reflection were that participants would reflect on the recipe-preparation process through writing and oral discussions: (1) as they were executing the recipe step-by-step, by talking about what they were seeing, and by recording their observations in the software or in charts we provided; (2) when they finished and analyzed the results of their recipe in the software or in charts we provided; (3) during big-group discussions when they were sharing their plans, results and experiences; and (4) when they were planning their recipe alterations.

The episodes highlighted in this section will show how the patterns of sensory and social engagement supported the usage of observational posters (Episodes 5.5, 5.16, 5.18), reflection pages (Episode 5.17), and planning pages (Episode 5.17). In Episode 5.19, I highlight the sensory and social engagement patterns that fostered participation in the big-group discussions.

5.4.3.1 Continuous Monitoring of Others Provides Support for Oral and Written Reflection

Recall that Episodes 5.5 and 5.18 highlighted the role that continuous monitoring of others played in prompting KJ and William to taste and make descriptive observations about the pizza dough their group was preparing. In addition, I found that continuous monitoring created the circumstances for KJ and William to recognize the opportunity to taste the pizza dough, to make verbal descriptive observations about the dough, and to take up the affordances of the *five senses charts* by recording their observations of the tastes and textures of the dough in the chart. While KJ did not explicitly say that he was going to use the five senses chart, or even write down his verbal observations when he decided to taste their pizza dough, he eventually used the five senses chart to record observations he and William had made (See Episode 5.5).

We created the *five senses charts* to promote reflection-in-action because we knew that participants would need some help making observations, especially while they were preparing the recipes. While having the five senses chart in the participants' workspace did lead participants to record some observations, they still didn't record an abundance of observations when KJ agreed with Craig's assessment that the group did not record "enough" observations. However, despite participants not always recording their observations, this series of episodes provides insight into the conditions of use in which the boys found meaningful use of this designed artifact for reflective purposes.

My interpretation of these episodes suggests that KJ's recording of observations was not motivated by meeting the program's expectations with regard to recording observations, but rather was motivated by opportunities to explore artifacts that had sparked his interest while participating and tasting the dough. For example, when he found out that William had not recorded the observation, he was disappointed but did not record the missing observation either. If his goal had been motivated by meeting the program expectations, I would have expected him to have recorded the missing observation when he found that William had not recorded it and when he realized that they had not recorded enough observations in general. He did not do that. Thus, my interpretation is that the boys' usage of the chart was not motivated by, or targeted at, fulfilling what they thought was expected of them, despite the chart's presence in their workspace. Episode 5.5 also shows how individual reflection can spark collective reflective discussion. In this episode, KJ's interest in tasting the dough and describing it sparked William's interest, and a discussion about the taste and texture of the dough ensued. This is significant, because many of the observations in the five senses chart were KJ's individual reflections. However, because the boys had made the observations together, KJ made a point of insisting that William record his observations as well. This is evidenced by the fact that KJ remained at the table looking at the Five Senses Chart even when the other boys in the group went to wash their hands after they finished kneading the dough and set it aside to rest.

Episode 5.17 from Session 5 also highlights the group's consistent adoption of the practice of monitoring each other and checking to make sure that no mistakes were made, and illustrates how this promoted usage of the reflection posters and Recipe Retry Day planning sheets. Recall that Brett was watching as Craig wrote his reflections on the reflection poster, and when Craig was finished, Brett wrote more observations on the poster (1:03:08 - 1:03:45). Also recall that KJ wrote his reflections on the Recipe Retry Day planning sheet (1:03:45), and later, Craig and William looked through the planning sheet and recorded additional notes.

This is significant because not all of the groups engaged in this process, yet those that did engage had similar patterns of social and sensory engagement to this group's patterns and did learn in similar ways. This is also significant because it was often the case that only one participant recorded observations and those observations were not reviewed or referenced by other participants. But here we see that this group was in fact engaging in this process voluntarily because they had already used it throughout the recipe-preparation process. Lastly, Episode 5.17 is significant because we wanted participants to collectively reflect, and this group developed their own process for doing so. As you will see in Case Study #2, such written reflection was not always done voluntarily, nor did other group members review what others had written.

5.4.3.2 Collaborative Decision-Making Provided Support for Oral Reflection during Big Group Discussions

When we were designing KSI, one of the reasons we created the big-group discussions was to provide an opportunity for participants to orally reflect on their small-group experiences. During the semi-structured activities, the big-group discussions were meant to allow the participants to share their experiences preparing the recipes, to compare and contrast the artifacts of their recipe variation across all the small groups, and to draw conclusions about the roles focal ingredients played. For the Recipe Retry Days, the big-group discussions were designed to allow participants to talk about their plans for adapting the recipe to their preferences and to get feedback from other participants about the feasibility of their plans. In addition, these discussions were designed to give participants the opportunity to report back about some of the challenges they had encountered when executing their plan, and the final results.

I found that it was very important for the boys to have experiences in the small-group activities to prepare them for contributing to the big-group discussions. In particular, I found that the boys' collaborative decision-making experiences while in the small-group activities allowed the participants to reflect on their knowledge of how yeast works and helped them to orally share the recollections of their science-based reasons for adapting the recipe procedure. In addition, this collaborative decision-making provided the boys with a shared experience upon which they fluidly and interchangeably reported during the big-group discussion.

Episode 5.19 provides an example of the depth and interchangeable nature of the boys' reflection on the recipe-preparation process during the big-group discussion. This episode took place at the end of Session 8, a Recipe Retry Day during the big-group discussion. On this particular day, the boys made cookies with yeast. They used the cookie recipe and substituted yeast for baking powder, which the original recipe called for. To properly substitute the ingredients, the boys had to devise a very intricate process for managing the reaction of the yeast. In particular, they had to devise a three-bowl process, discussed in Episode 5.13, where they had one bowl for dry ingredients (e.g., flour and sugar), a second bowl for wet ingredients, and a third bowl for warm water to activate the yeast. While preparing their cookies-with-yeast recipe, the group collectively prepared the recipe with some group members more heavily involved (i.e., Craig and Brett), while others looked on and provided support by getting ingredients and other resources as they were needed (i.e., William and KJ).

In Episode 5.19, notice how the boys were able to fluidly alternate narration of their recipe-preparation process during the big-group discussion at the end of Session 8. Notice that the boys often started talking at the same time, and/or cut into each other's explanations mid-sentence. For example, notice that at the beginning of the transcript, every conversational turn shift occurred between Brett and Craig as they explained to the group what they had done to create their cookie recipe. The second set of conversational turn shifts began when Craig explained their three-bowl process, and KJ cut in to admonish the girls for hassling them about using the girls' bowl. After this point, KJ and Craig went back and forth, talking about how they'd used the three bowls to complete their experiment. Then, the third set of fluid conversational exchanges transpired between KJ and Craig, about how their recipe procedure had captured the air that the yeast had produced.

Episode 5.19:
Session 8: Ending Discussion
Christina: "Brett."
Brett: "So we…"
Christina: "So tell us which ones are your cookies?"
Craig: "The white ones."
Brett: [pointed to the cookies]
Brett: "We took out the BS and BP and put in yeast."
Craig: "And we added water to the recipe."
Brett: "Because we need the water to wake up the yeast."
Craig: "Then we put the yeast and the water in a separate bowl from the dries and the wets. Then we mixed it all together and it sort of turned into dough but we couldn't knead it."
Brett: "We used three bowls because we did one for the yeast because we didn't want to add that one yet because we wanted to capture the carbon dioxide."
CMG: "OK."
Craig: "Then we had a bowl for the wet ingredients and for the dry ingredients
KJ: "So stop bugging us about the 3-bowl stuff." [This is addressed to the girls whose bowl they took when they needed an extra bowl. These girls had been pestering them the entire session about them taking their bowl.]
CMG: "OK, so I hear that you used one bowl for the yeast and that you added water to the recipe to wake up the yeast. Then I heard something about catching the carbon dioxide. Tell me a little more about that."
KJ: [KJ tries to tell her, but as his mouth opens, and before he can say anything, Craig speaks over him.]
Craig: "Well if we put the sugar in with the water and the yeast it wouldn't rise. Well it would but it (pause) then the carbon dioxide (pause) and the yeast would just expand and then it would be hard to mix."
CMG: "So how did you avoid that then?"
Craig: "We used three bowls."
Craig: "We didn't put the sugar in with the yeast and the water. We put it in with the dry ingredients."
CMG: "OK, how did you mix this stuff together?" (waving her hands to denote mixing)
[Craig, Brett, and KJ start talking at the same time]
KJ: "We then put it in the bowl." (using his hands to make a dumping motion)
Brett: "We mixed it."
Craig: "We used…"
CMG: "So you just put in everything at the same time." (using hand motions to denote pouring in everything at the same time)
KJ: "No. (using hands) No we…" (He gets cut off.)

Craig: "No we put the dry ingredients with the butter. (This refers to the butter that was creamed with the sugar.) And then we poured (makes a pouring motion with his hands) in the yeast and water."

1:21:32
CMG: "And that does what? How does that capture the, capture your air bubbles?"
[KJ and Craig talking at the same time]
KJ: "The dry products…"
Craig: "Because the dry products make a…"
KJ: "Act as a balloon." (making arm and hand motions to denote a balloon blowing up)
Craig: "Balloon."

In this episode, three of the four boys were able to fluidly transition between one another while recounting how they'd prepared the cookie recipe. In particular, I believe their ability to talk about the recipe-preparation process and the changes in the artifacts and the science-based rationale behind their decision to prepare the recipe the way that they did in a fluid manner during the big-group discussion reflected their process of collaboratively coming to a decision about how to prepare the recipe during the small-group activity. Thus, the ways the boys engaged in the small-group activities shaped the way they reflected in the big-group discussion.

In Figure 5.7, I highlight the parallelism between the two explanations the boys provided for how and why they adapted the cookie recipe to use yeast. The first explanation occurs during the big-group discussion at the end of the session (in Episode 5.19 in Figure 5.7). The second explanation occurred during the discussion the boys had earlier in the session about how to adapt the cookie recipe to use yeast when Craig was talking to the group about his conversation with Christina concerning the number of bowls to use in preparing the recipe (in bold from Episode 5.13 in Figure 5.7).

In Episode 5.13, Brett responded to Craig's question about where to put the sugar by initially saying that they should just put the water with the yeast, implying that they leave the sugar out. However, Craig suggested that they need to add the sugar as well because the yeast eats the sugar. Then KJ suggested in words and gestures that they need to prevent the gas that the yeast produces when it eats sugar from escaping so they should be putting the sugar with the dry ingredients. This episode shows that the interchangeable articulation of their plans in the big-group discussion was based on their collaborative decision-making process that took place during the recipe-preparation process.

In Episode 5.19 Brett began telling the participants and facilitator during the big-group discussion that they'd used three bowls to control the way they trapped the carbon dioxide. This explanation took into consideration the scientific explanation of why they did not put the yeast with the sugar as offered by KJ in their conversation in Episode 5.19, although it was never explicitly summarized in that way. Next, Craig cut in and told the big group they'd put the sugar with the butter in the dry ingredients to keep it separate from the yeast to prevent the yeast from producing carbon dioxide before they were ready. Then KJ responded to the facilitator's question about how they captured the carbon dioxide using the same gestural demonstration he'd used in the small-group discussion while telling the big group that the dry ingredients create a balloon that captures the carbon dioxide. Notice that both Craig and KJ took turns fleshing out this explanation.

Episode 5.13:
Session 8:
23:39
Craig: "We have to decide if we are going to put the sugar with the yeast and water or if we are going to put the yeast with the dry ingredients. She said we have to have three bowls: 1 bowl for the dry, 1 for the wet, and one for the yeast and water."

23:45
Brett: "I think just the water and the yeast."
Craig: "I think the water, the yeast, and the sugar because the sugar needs the water to wake it up. I mean the yeast needs the water to wake it up and then the yeast eats the sugar."

KJ: [Inaudible exchange between Craig, William, and KJ. KJ raises his hands above his head enthusiastically. He later repeats this gesture and the ending discussion, which denotes gas escaping.]
KJ: "So we put the sugar with the dry stuff for the dough."

24:06 [End]

Episode 5.19:
Session 8:
Brett: "We used three bowls because we did one for the yeast because we didn't want to add that one [yeast] yet because we wanted to capture the carbon dioxide."
.
.
.

Craig: "No we put the dry ingredients with the butter (this refers to the butter that was creamed with the sugar) and then we poured [makes a pouring motion with his hands] in the yeast and water."

1:21:32
CMG: "And that does what? How does that capture the, capture your air bubbles?"
[KJ and Craig talking at the same time]
KJ: "The dry products."
Craig: "Because the dry products make a…"
KJ: "Act as a balloon." [making arm and hand motions to denote a balloon blowing up]
Craig: "Balloon."

Figure 5.7 Parallelism between the boys' explanations for how and why they adapted the cookie recipe to use yeast

In summary, the ways the boys engaged socially in the small-group activities shaped the way they reflected in the big-group discussions later. In particular, the group's collaborative decision-making process provided the boys with a shared experience that they could collaboratively refer back to and discuss later. And the collaborative manner in which they initially discussed how to adapt the recipe was also used to interchangeably and fluidly take turns explaining this decision to the big group.

5.4.3.3 Summary of Opportunities for Reflection Created through Sensory and Social Engagement Patterns that Provided Support for the KSI Activities

Subsections 5.4.3.1 and 5.4.3.2 highlight how the boys took up the affordances for reflecting orally and in writing using the sensory and social engagement patterns they engaged in during the small-group activities. In particular, I identified the way that sensory and social engagement patterns fostered the use of both written reflection tools we designed and productive and fluid discussions of participants' experiences during the small-group activities of preparing their recipes.

For example, patterns of constant monitoring of others and artifacts gave participants content to reflect on, in written and oral forms. During opportunities for engagement in written reflection, participants' constant monitoring of others and artifacts was also seen in the ways they checked others' reflections, and appended the reflections with their own ideas. In addition, a fluid understanding of the recipe-preparation process and collaborative decision-making fostered oral reflection. This made it easy for participants to take turns during big-group discussions to speak about their recipe-preparation processes and scientific justifications for those processes. These patterns of cognitive engagement were significant because it was often hard to get participants in learning-by-doing activities to reflect (and do so very deeply) and share this knowledge amongst all the group members equally.

5.4.4 Making the Connection between Cognitive Engagement and the Resultant Learning

The different dimensions of engagement outlined in this chapter for the boys armed them with a more than adequate awareness and understanding of the recipe-preparation process for making pizza with yeast, and for observing how yeast worked to produce foam in their water bottles and CO_2 that blew up the attached balloon. In general, I found that it was important for the boys to have taken an active interest in the recipe-preparation process and to have seen some of the cooking phenomena related to the role the focal ingredient played in the recipes they'd created. In particular, I found that the boys' sensory and social engagement experiences while in the small-group activities drew their attention and sparked and sustained their interest, which provided them with the firsthand and secondhand experiences that helped them to orally share the recollections of their experiences and to recount these experiences.

It is clear from this transcript and its analysis that despite the role participants took on, whether their experiences were firsthand or secondhand, and how long they stayed in a particular role, the small-group discussions provided them with content to reflect upon. Their ability to have the firsthand and secondhand experiences, I argue, was facilitated through the group's practice of continuous monitoring and attending to verbal cues during the small-group activities.

In Episode 5.20, all KSI participants were clustered in a group to discuss the science behind yeast and the roles they saw it play in their activities. In this episode, Craig and the other boys listened as the other participants shared what they knew about yeast, and then Craig shared his understanding that yeast was a living thing and also shared his experience of the yeast-air balloon water-bottle artifact.

Episode 5.20:
Session 1:
8:48
Christina: [trying to get everyone's attention] "If I can get everybody's attention."
Christina: "So we talked about yeast today, right?"
Someone: "Yeah."
Christina: "So can someone tell me what yeast do?"
Christina: "Ah yes."
Sara: "Um, it usually makes things, um, rise."
Christina: "It makes things rise."
Christina: "Someone else tell me how."
Student: "It eats the sugar out of it and it makes it grow because it multiples."
Christina: "It multiples."
Christina: "What did you want to say?"
Craig: "Yeast is a living (Christina interjects. Then he repeats.) thing."
Christina: "It is a living thing."
Christina: "What is it? (Pause) It's a fun-g-us (elongated), right? So what's going on in your water bottles?"

9:24
Craig: "OK, our water bottle like um. Our water bottle just sort of went bigger and bigger after we put the sugar in. And this started to foam up right it started to foam up and then it released the air into the balloon as it was getting bigger and bigger. Then it was putting air into the balloon.
The carbon was making it blow up. Then it lets off carbon dioxide."

This episode served several purposes in illustrating the boys' cognitive engagement in big-group discussions: First, it provided them with information about yeast (e.g., yeast makes things rise and yeast eats sugar). And second, Craig had an opportunity to share what he knew about yeast (i.e., "Yeast is a living thing."), which he had gained from overhearing a conversation Christina had with the girls in the group next to his during the small-group discussion. Thus, the discussion provided them with verification of something they'd already figured out earlier.

In addition, Craig was able to build upon the contributions of the other participants, and to personalize the explanations that he'd heard of how yeast works, by using his bottle to demonstrate what yeast looked like when it multiplied (denoted by the foam), and the effect that yeast had when it was multiplying and producing carbon dioxide that blew up the balloon. Recall from Episode 5.2 that the boys had an in-depth discussion about the foam in the yeast-air balloon artifact as a result of both their own continuous monitoring of the artifact over time and their continuous monitoring of each other. This created an opportunity for the group to reflect collectively upon the history of the artifact.

Thus, Craig's explanation was derived from a number of sources: (1) Craig and the other boys in his group had a conversation about the history of the foam in the water bottle, which suggests that he was monitoring the changes in this artifact; (2) he was present for a discussion Christina had with the girls when their balloon came off of their water bottle and Christina explained how yeast eats sugar to reproduce; and (3) he was also present and attentive to a discussion Christina had with the other boys' group, which used water that was too hot and killed the yeast, thus reinforcing his understanding that the yeast was a "living thing".

Thus, taken together, Craig's explanation and use of his water bottle to explain how yeast works was his way of personalizing and applying the explanations he'd heard about how yeast works. Apart from these experiences, Craig and his group had no access to Christina or any of the other facilitators, so the explanation he gave here must have been based on a conversation he'd overheard previously from the facilitators. Thus, constant monitoring of the preparation process and artifacts, as well as other people, played a crucial role in the development of Craig's and his group's understanding of how yeast works.

The boys' knowledge of how yeast works was enhanced by the interactive reading of PowerPoint slides he and his group engaged in during Session 4 of the program. This information, coupled with his previous experiences, helped him and his group members to build a robust understanding of the ways that yeast works; so much so in fact, that in Episode 5.13 Craig was able to use his knowledge of how yeast works to start a conversation with Christina to figure out how best to apply that knowledge in adapting the cookies-with-yeast recipe.

Brett and KJ showcased their understanding of how yeast works in the two posters (Figure 5.8) they created during the KSI Program's last session.

Figure 5.8: Brett's poster (left) and KJ's poster (right) showing their understanding of how yeast works

These detailed posters showcase their understanding of the relationship between yeast, sugar, and water. The notion that the yeast is a living creature became central in their anthropomorphic characterizations of these three ingredients. Brett and KJ's second poster to the right in Figure 5.8 features an equation using the three anthropomorphic characterizations of the yeast, sugar, and water (i.e., "yeast" + "sugar" = Rising). In addition, the poster contains a descriptive narrative of the process by which yeast and sugar create carbon dioxide: "Yeast eat sugar [drawing of a PAC-man, depicting yeast, chasing a ghost, depicting sugar] And… it Reproduces!...And release CO_2…water + yeast put together makes the yeast eat sugar and reproduce. But you need water to wake it [yeast] up. [drawing of a pizza with arrows pointing up out of the crust] So ... the dough acts as a balloon and traps the yeast [CO_2] which makes it rise."

As noted earlier in this chapter, Brett and KJ's first poster to the left in Figure 5.8 features anthropomorphic depictions of yeast, sugar, and water in an equation that equals rising and they write that "yeast needs partners to rise". Also included on this poster are drawings of a "tall" thick crust pizza slice and a "huge" cookie under the statement "more yeast equals". Under these pictures is written "less yeast equals" with a drawing of a "thin" crust pizza slice. The food drawings are pictorial representations of the results of their Retry Day explorations of yeast.

Many of the pictures and descriptions depicted in these posters arose from their experiences preparing recipes, observing cooking and science phenomena, seeing the results of their recipes, making hypotheses about the role of the ingredients and adapting recipes to test their hypotheses, and making rules of thumb during their small-group activities. Furthermore, the content of this poster and other artifacts suggests that they learned through their participation in the designed activities, conversations, and interactions with resources and materials we intended with the design of KSI.

In summary, this discussion of the boys' cognitive engagement suggests that it was fostered through the group's shared sensory and social experiences. The group's practice of constant monitoring was very important for their intentional sensory, social, and cognitive engagement. In particular, their sensory engagement and constant monitoring, and the interdependence of activities and people, promoted the development of social engagement practices that further developed opportunities for the participants to cognitively engage. Moreover, I have argued that the boys' patterns of cognitive engagement were consistent with their sensory and social engagement patterns in form and function.

5.5 Chapter Summary- Patterns in Dimensions of Engagement that Promote Learning

This case study offers a glimpse into how a group in KSI, a learning-by-doing learning environment, developed sensory and social engagement practices over time that promoted their cognitive engagement. In addition, it identifies the particular ways that sensory and social engagement fostered learning in a hands-on learning environment.

Overall, I found that participants' goals were not always identical or compatible with the KSI Program's goals during the small-group activities. Participants were focused on getting and "having-their-turn" measuring, stirring, or otherwise preparing the recipe. The KSI Program's goals were aimed at providing opportunities for participants to have firsthand experiences cooking, with the goal that they would actively make observations and notice changes in the artifact as they were preparing it, and that would drive them to wonder and ask questions about the role of the focal ingredient.

While the mismatch in goals often meant that initially participants were physically engaged, but not cognitively engaged in the activities, I found that the strategies participants used to "get their turn" were also useful in giving participants the desired firsthand and secondhand experiences that they could reflect on later. Reflecting on these experiences later allowed them to learn about the target science phenomena.

The basic implications of the sensory engagement patterns I found suggest that participants' tactile, visual, and verbal engagement provided a bridge between the participants' goal of "getting their turn" and the goals of KSI. In particular, these forms of engagement allowed participants to gain the majority of their firsthand and secondhand experiences that later helped them learn about the science phenomena.

Tactile engagement provided the boys with firsthand experiences they needed to later reflect upon the science content the activity was designed to facilitate. Specifically, tactile engagement promoted participants' noticing of phenomena of interest and changes in artifacts. In addition, participants gained knowledge of the preparation process of artifacts. Furthermore, this tactile engagement was afforded through piqued interest, and this interest was sustained by continued tactile engagement and more firsthand experiences. These experiences were necessary for later reflection.

In addition, visual engagement provided a bridge between the participants' goals of actively participating in the recipe-preparation process and the KSI activity goal of noticing changes in the recipe as a result of adding the focal ingredient. In particular, participants' continuous monitoring of artifacts and others facilitated the bridge between the two goals. Continuous watching of artifacts:

(1) piqued interest;
(2) caused the noticing of phenomena and changes in the recipe being prepared;
(3) resulted in conversations about artifacts and their histories; and
(4) led to comparisons of artifacts at different times in their development or their different characteristics.

Artifacts with persistent presence and artifacts with open affordances that enabled participants to see changes within them afforded continuous monitoring of artifacts.

Continuous monitoring of people within or across groups promoted:

(1) meaningful noticing;
(2) comparisons of artifacts;
(3) conversations between participants in the same group or across groups; and

(4) further noticing and comparisons.

In addition, continuous monitoring of others across groups often led to watching changes in participants' own behaviors and practices, and resulted in the shifting of participants' behavior, from less active engagement to more active engagement in the recipe-preparation process. Facilitation occurred

(1) by imitating others' behaviors (e.g., picking up an artifact to see what's going on inside of it); and

(2) through being inspired to take on new roles in their group and to interact with their artifacts in different ways (e.g., seeing someone taste the dough, then deciding to shift behavior from watching other group members' kneading the dough, to tasting the dough and making and recording observations of what it tasted like).

The resultant shift in behavior created by continuous watching of others was afforded by the shifting of participants' attention and activity away from their current activity in order to notice something new.

Furthermore, continuous monitoring within groups promoted:

- recognition of appropriate materials;
- active recognition and avoidance of mistakes; and
- awareness of artifacts' histories.

All of these affordances minimized opportunities for the phenomena not to occur, and potentially made drawing conclusions about the role of an ingredient across groups' artifacts difficult.

Overall, continuous visual monitoring of others fostered new ways for participants to participate in the activities of their groups, and to take up the goals intended by the activities. This was afforded by the abundance of activities that could be attended to when each participant in a group was focusing on a different task or played a different role in the preparation of a recipe or experiment.

In summary, three conditions seemed to afford or promote the kinds of participation that led to learning:

(1) Support for participants positioning themselves to have their turn. In this enactment, this included their ability to continuously monitor artifacts and others, to gain and retain access to needed materials, and their development of the social practices that led to collaborative sharing of information and decision-making.

(2) Affordances for activity coordination to happen in a way that includes the whole small group. In this enactment, this included the ability of group members to see and hear each other, the ability of group members to see and hear the activities of other groups, and the way the group members divided responsibilities (i.e., their positioning), such that they needed each other to complete recipe steps. For example, in making the yeast-air balloons, each participant had possession of different materials or tools all needed to complete the job.

(3) Affordances for focusing attention on important phenomena and processes. This refers to the placement of materials and closeness of group members to each other. They were able to see important phenomena and processes

> because the artifacts they and other group members were creating were persistent in their workspace and the artifacts themselves had affordances for being seen from multiple angles and perspectives. This in turn allowed continuous monitoring once their interests were piqued, affording awareness of artifacts' histories and changes and of how activities were being carried out. All of this provided grist for individual and collective reflection.

In the next case study, I will show how these same patterns of sensory and social engagement were hindered in many ways, and subsequently, how learning was hampered. Then, in the cross case analysis that follows in Case Study #2, I will show how configuration of the learning environment fostered sensory, social, and cognitive engagement, as well as the subsequent learning seen in Case Study #1, and how different configurations promoted and/or hindered learning in Case Study #2.

CHAPTER 6

CASE STUDY #2: INHIBITED ENGAGEMENT DURING SMALL-GROUP ACTIVITIES; ACTIVE ENGAGEMENT DURING BIG-GROUP ACTIVITIES MAKES UP FOR IT

> "In KSI, we just cook and figure out the science in cooking. Science, in KSI can be fun. Science, some different science can be fun, hands on science can be fun. And I can learn, and I can catch on easier… In KSI, I do more hands on stuff and it's more fun. In science, I just sit there and look at a book. And like in science, the teachers tell you to open a book and read by yourself, some people really don't read the book, they'll just be sitting there pretending like they're reading or something. A lot of times when the teacher asks you a question, *you don't know*. And they can tell you're not doing nothing. [But] in KSI, you really know you're doing something. People really know you're doing something. They can really tell and can see you doing stuff and studying and learning and talking about it. Like, when you talk about it like you know something about it and they can tell you did something."
>
> *- Malaysia; Interview after the conclusion of the program from the only interview we have with Malaysia*

This chapter offers insight into ways sensory, social, and cognitive engagement were promoted in the big-group discussions but were inhibited during the small-group activities and how such fluctuation in participant engagement impacted learning in a learning-by-doing learning environment. In this case study, I focus on a 6th grader, Malaysia, who learned a lot about the science of how starches thicken liquids from her experiences in the big-group activities but whose inhibited sensory and social engagement in the KSI small-group activities impeded her overall cognitive engagement and limited the depth of science she learned in KSI. I also use this case study to gain a better understanding of what inhibits an inquisitive and reflective participant from engaging in and learning from the small-group activities but not the big-group activities in the ways we expected participants to learn.

This case study describes a non-ideal but common learning trajectory of participants in KSI, in which a participant's attendance and participation prevented her from participating in the program as it was designed and where she forged a new learning path to learning what she initially missed. Malaysia came into Enactment #2 of KSI during Session 15. She missed the first 10-session unit on leavening and half of the second 10-session unit on thickening. In missing the first 4 thickening unit sessions, she missed all of the semi-structured cooking and science activities that would have allowed her to experience the science of thickeners firsthand. However, this case is really interesting, because despite missing these opportunities, Malaysia was able to show understanding of some of the science behind how starches thicken food and how to use the starches for that purpose.

In addition, Malaysia's engagement in small-group activities was different than we had expected because of limited firsthand opportunities with cooking phenomena. She was limited not because of a lack of curiosity. Rather, she did not take up affordances for firsthand experiences as expected. Sometimes this was intentional on her part; at other times, circumstances limited her ability to grasp affordances, and at other times, important affordances were missing.

Malaysia came into KSI, then, at a time when much had already happened, and she could have been overwhelmed by all of the action competing for her attention. Like most participants, she directed her attention toward cooking and socializing, often multi-tasking between conversing with peers, preparing a recipe, trying to understand what KSI was all about, and taking direction from the facilitator. Given the relatively short time that Malaysia participated in the program, and the factors competing for her attention, it is important to seek answers to the following questions:

(1) How was she able to learn any science about starches after she missed the initial first-hand experiences?

(2) How did missing those experiences impact her ability to take up the affordances of small-group work? How did she get around that?

(3) What else, if anything, inhibited Malaysia from learning during the small-group activities?

(4) Did Malaysia's group ever engage in the engagement patterns of the boys? If so, under what circumstances?

In this chapter, I present both the factors that inhibit Malaysia's taking up of affordances (personal, programmatic and situational) during small-group activities and factors that led her to taking up of affordances (personal, programmatic and situational) during big-group activities and led to her learning nonetheless.

6.1 Background

6.1.1 Learning

Before we begin to address these questions about how Malaysia's learning developed in the KSI learning environment, it's first necessary to highlight what she did learn in the program.

When Malaysia entered KSI, it did not appear that she knew anything about starches and how they work. Throughout her participation in the program, she was often attentive to science explanations and results from previous experiments she had missed, and she frequently asked questions to gain a better understanding of concepts during big group discussions. By the end of the program, Malaysia learned two main things about starches: (1) how to use starch thickeners in preparing recipes; and (2) the science behind how starches work.

During Session 15, Malaysia's first day in the program, the entire session was a big-group activity where the group examined four variations of the strawberry pies they made during Session 14. The goal of the activity was to devise rules of thumb for how much cornstarch to use in the strawberry pie filling recipe to get the perfect texture that allows you to cut a slice without the filling oozing out. During Session 15, one of the participants, Amber, used the word "congealed" to describe the texture of one of the strawberry pie fillings. Malaysia did not recognize the word so she began asking questions about it. Thus, her understanding of congealed developed through engaging in a series of conversation about the meaning of the word with peers and facilitator and through exploring the thickness of the strawberry pie fillings that had been prepared in the previous session. By the end of this session, Malaysia developed an ambiguous definition of congealed. When used by Amber, it was meant to describe foods that were stuck together or solid, but Malaysia used the word to describe both loose and more solid textured strawberry pie fillings.

During Session 16, Malaysia's second day in the program, the big-group discussion was focused on the science of how starches work. She listened attentively to the facilitator's science explanation about the way starches work that was given to all of the KSI participants. From this explanation, she was able to understand enough about how starches work to ask applicable questions and to articulate that she understood that starches absorb water and swell, and that the amylose and amylopectin in the starch granule is what makes the starch absorb water (though it is not clear what she understood about amylose and amylopectin). During this discussion, the facilitator used Cocoa Puffs® to represent starch granules. Although Malaysia missed part of this discussion because she had to take a call from home, she was still able to articulate her understanding that the Cocoa Puffs® represented starch granules. She even asked if they would swell in her mouth when she ate them. Her question signified that she understood the explanation well but had failed to understand the abstract nature of Cocoa Puffs as a "representation" of a starch granule and not an actual starch granule.

At the beginning of Session 16, Malaysia had some understanding that the range of textures in a recipe can span from preserves to jelly to Jell-o® and that somehow starches could make a substance become more congealed (though she did not fully understand what congealed meant). However, since she did not actually know what amounts of cornstarch had been in the pies that were examined in Session 15, she had not made the association between the amounts of cornstarch and the texture that resulted.

Thus, the Cocoa Puff® science explanation, discussed during Session 16, was the first time she was encountering the idea that the amount of cornstarch in each pie could make a difference in how thick it would become. By the end of Session 16, Malaysia had strengthened her understanding of the relationship between amount of cornstarch and thickness, and she seemed to understand that using more cornstarch makes a food more congealed. During Session 18, Malaysia demonstrated that she understood the science explanation about the starches absorbing water conveyed by facilitator during Session 16, when she responded to a facilitator's prompt about why they were adding a certain amount of potato starch and potato flour to so much water. She said that the starch was going to absorb the water. During the small-group activity, Malaysia listened and looked on intently as Christina tried to help her and her partner, Nina, understand the role heat played in starches' absorption of water. Christina used science note cards[2] that described that starch granules can absorb a small amount of water without being heated but absorb water and swell when heated. She used these cards to help the girls think about when they should stir in the potato starch to reduce the clumping. Later in the session, Malaysia was able to make a connection between the clumps of potato starch in the pot being the result of the potato flour coming into contact with the water on the wet spoon, and the potato

[2] The science note cards were created to provide participants with visual and textual descriptions of important scientific concepts. Participants were introduced to these cards by facilitators during small-group activities at times when just-in-time science explanations were important for promoting understanding of the scientific principles at work in the activity.

starch absorbing the water and sticking to one another before they got into the pot. Thus, she explained that starch grains in the potato flour absorbed water, and that was the reason they should not use a wet spoon to add the starch to the mixture since it would cause lumps. It was also during this session that Malaysia listened to an explanation Christina provided as to why the ravioli got bigger (the starch in flour used to create the pasta absorbed the water in the pot and expanded) when they were cooking.

During Session 19, Malaysia had the firsthand experience of making homemade pasta. She learned that she could sprinkle flour on the table to prevent the pasta dough from sticking to the rolling pin and table because it absorbed some of the moisture from the moist dough and created a barrier between the table/rolling and the dough. Thus, she was able to derive a very practical application from her knowledge about starches absorbing water- how to prevent the pasta dough from sticking to the table in this case.

During Session 20, Malaysia listened to and participated in the small-group conversation Christina led, aimed at pulling out what they knew about why starches absorb water. During this conversation, Malaysia listened and sometimes asked the other girls for clarity on what they said. Other times, she repeated what the other girls said in response to Christina's questions, which prepared her for the presentation for the parents later that evening. Looking at the note cards about the science behind starches we'd provided each group and for which Christina referenced during a discussion on Day 18 during the small group about the science of how starches absorb water, Malaysia, without prompting, wrote down some notes about things she wanted to present during the parent presentation. She then co-presented the answers to the questions that she and her group composed in reply to Christina's questions. In addition, she demonstrated that she understood or at least recalled the explanation that Christina had provided two weeks earlier about the pasta expanding in the water because it absorbed the water. However, she took it a step further by adding specific details about her experience that she associated with that knowledge. Namely, she recognized the change in the ratio between the pasta and the filling. In particular, she observed that the pasta was getting bigger because when they first made the ravioli, they were medium-sized and the filling took up a lot of the space in the ravioli; after they cooked them, the ravioli were much bigger and the filling was smaller.

It is clear that Malaysia learned content in KSI, and as such, this is not a case study of a participant who failed to learn in the program. Malaysia learned through the big-group discussions and one-on-one conversations with the facilitator in both the big-group and small-group activities. So the question remains, what inhibited her learning during small-group activities with peers?

6.1.2 Description of Learner

Malaysia was a sixth grader at New Hope Middle School while participating in KSI. In general, she was down-to-earth and energetic, had a great sense of humor, loved to tell stories, and was generally adept at communicating. She carried herself with confidence and competence; with strong self-assuredness, she spoke of being the type of person who could do anything she put her mind to, which included being a chef or model, and working with computers. In addition to her confidence, Malaysia was very inquisitive and full of questions, aware of what helped her learn. Additionally, she had a keen awareness of when she had gaps in her understanding and when new information did not fit her current understanding. Furthermore, Malaysia was deeply reflective about the whole enterprise of KSI. She often wanted to know what research was when we were conducting experiments on her, and what we would do with all the video we were collecting. In addition, Malaysia was very curious and always eager to participate in the recipe-preparation process.

Despite Malaysia's confidence, inquisitiveness, and reflective spirit, she did not exhibit these characteristics during the small-group discussions and activities, in sharp contrast to her behavior during the big-group discussions. It was clear that Malaysia's goal for the small-group activities was to prepare the recipe so that she could take it home to share with her family. She frequently asked facilitators, "Are we ever gonna be taking these home?" and "Can we have two separate ones?" Thus, although this called into question Malaysia's interest in learning science from the program, it was difficult to imagine that she was not interested in the science because of the way she eagerly engaged in big group activities.

Malaysia struggled to engage in her school's science class. At the time of the study, she was struggling to get passing grades in science and other classes. Her Mom stated during interviews that Malaysia had always been a good student, and that she was still trying to get acquainted with the new freedoms of middle school, social groups, and academic expectations. Middle school was the first time in her life that Malaysia struggled to get good grades in science and some of her other classes.

Based on Malaysia's reflective quotation on her science class at the beginning of this chapter, it was apparent that she just was not motivated by science class and thought it was boring. In personal conversations with her, she revealed that she did not like science and had trouble understanding the content; consequently, she often fell asleep in class, and her grades in science were not good. Malaysia attributed her boredom with science to the lack of hands-on activities and to staring at a textbook. This notion of boredom was further supported by her science teacher's observation of Malaysia's comfort with asking questions in science class but lack of follow-through in completing her work.

Malaysia's aversion to "science" and doing "school-like" things was observed a number of times during her participation in KSI. While Malaysia actively engaged in science contents and concepts in the context of cooking, when we used "school" words like "density" and "ratio" and "writing", she often openly protested and shied away from participating in KSI. My goal for this case study is to highlight the various ways that Malaysia's inhibited sensory engagement negatively impacted her engagement in and learning from the small-group activities. I do this in hopes of gaining a better understanding of what inhibits inquisitive and reflective participants from engaging and learning from learning-by-doing activities in ways we would expect them to.

Malaysia's participation in large-group discussions ameliorated much of the negative impact her small-group experience, and indeed, by the end of Kitchen Science Investigators, Malaysia was far more comfortable with engaging in science, even as part of science class (Clegg, 2010). This case study, however, only focuses very lightly on that part of her experience and on the affordances of large-group discussions for promoting learning in learning-by-doing learning environments.

6.2 Sensory Engagement

An important goal of inquiry science is to ensure that participants have adequate firsthand exposure to science phenomena while engaged in hands-on inquiry activities.

This requires getting participants (1) to notice (see and touch) phenomena; (2) to recognize and appreciate changes in phenomena; and (3) to hear verbal cues about important things to notice and see. However, as I found in both case studies, the participants were often more concerned with the "doing" involved in the recipe-preparation process than they were with noticing important phenomena. This suggests that while the goals of activities were meant to engage participants cognitively, participants sometimes were more motivated to engage physically. This was not the case for Malaysia. As the excerpts will show, Malaysia seemed interested in engaging in only some aspects of cooking, and not always the ones where interesting scientific phenomena were observable. She preferred cutting fruit, for example, to stirring pie filling. I try to uncover in the case study both why she was not as interested in some aspects of cooking as she could have been and why she was not noticing phenomena she could have been attending to.

The following subsections discuss factors that inhibited Malaysia from engaging her senses. In addition, I provide episodes that highlight the impact that inhibited sensory engagement had on her cognitive engagement in the activities.

6.2.1 Tactile Engagement

I found that there were a number of impediments to Malaysia's tactile engagement that inhibited her from participating in the activities in ways that would have given her firsthand experiences. In particular, KSI's firsthand activities/experiences included touching and tasting foods. Malaysia was initially averse to touching and tasting foods that were not appetizing to her. Thus, it was important to understand how not having these experiences limited Malaysia's ability to cognitively engage in the activities, and what impact this had on her later reflection.

Malaysia's reluctance to initially touch and taste the food artifacts that the KSI groups prepared inhibited her from making observations about the tastes and textures created by different amounts and types of starches. This reluctance prevented Malaysia from having the full breadth of experiences the program was originally designed to provide her with when making decisions about what starches to use to achieve the desired texture of dishes. This was important because tactile engagement was meant to provide participants with opportunities to personally connect with the KSI activities. In particular, this was an opportunity for a curious and vocal person like Malaysia to explore the different tastes and textures of the foods, to make observations, to share those observations with other participants, and to use the tactile understanding to make decisions about the proper uses of starches when preparing dishes.

Since Malaysia was not that interested in touching and tasting foods, it was not surprising that I did not find many episodes of her doing so in the small-group activities. There were a couple of episodes in particular from her participation in the big group discussion that highlighted her aversion. Episode 6.1 took place during a big-group discussion during Session 15, when the participants were trying to describe the differences between the four variations of strawberry pies they had created in order to learn about the role an increasing amount of cornstarch played in the recipe. In this episode, the participants were gathered in a semi-circle around a big table with the four pie variations lined up at the top of the table opposite the participant semi-circle. The participants were able to use both their hands and utensils to explore the textures of different strawberry pie fillings and other food artifacts like jelly and Jell-O ®, which were provided for this purpose.

Episode 6.1 shows that the participants and facilitators, TLC and JLK, were trying to determine which of the strawberry pie fillings and jellies were most appropriate for making fruit-filled sandwich cookies for one of the participants, Amber, who liked to bake. In this episode, Malaysia did not know what the word "spread" meant so she asked Angela to explain it to her. Angela explained what it meant to spread by demonstrating it to her. When it was Malaysia's turn to use the knife to spread the filling, she drew back in repulsion.

Episode 6.1: Spreadable – Session 15 - Learning How to Use Starch Thickeners
Context: The girls are passing around on the right different jellies, etc.
(0: 43: 40.6) JLK asks which we would use if we were going to spread on Amber's cookies.
Cyera: "Her cookies are good, when she makes them."
TLC: "Amber? Yeah, I've had Amber's cookies too. But so now, we're thinking about..."
Candyce makes an observation about which she'd want [the preserves] to spread on cookies, b/c it's more spreadable.
TLC asks which of the pies would be more spreadable.
(0: 45: 11.3) Candyce and Malaysia are given the knives to try to spread.
Malaysia: "How you mean spread it? What she mean?"
Angela: "Just go like that." [Motions with knife demonstrating how to spread]
Malaysia: [spreads the strawberry pie filling with the knife]
Malaysia: "It took a lot of guts to... with this."
TLC: "It took a lot of guts? What does that mean?"
Malaysia: "It looks nasty!"
JLK: "To spread it? It's just strawberries."
Malaysia: "Eeew, I'm bout to turn my back on strawberries."
JLK: "It's just strawberries and sugar and, you know..."
Malaysia: "I know!"
[She doesn't enjoy spreading the strawberries]

In this episode, Malaysia verbally shared her aversion to touching the pie filling, even with a knife, to the extent that she wanted to stop eating strawberries because the sight of the strawberry pies grossed her out. Thus, the extent of her aversion was conveyed in her inability to even discuss what it looked like with the facilitators. Accordingly, she was limited to engage in a conversation about the texture or taste because of the degree to which it disgusted her. This hindered her from being able to complete the activity of recommending a strawberry pie filling or jelly for keeping sandwich cookies together.

Episode 6.2 highlights Malaysia's aversion to tasting foods. In this episode, Malaysia and Nina were preparing potato filling for a ravioli dish of their creation. The goal of the activity was to create ravioli filling that had the consistency of mashed potatoes. They were using two different types of starch: potato starch and potato flour. Each girl was making a trial batch of the potato filling with a different starch to figure out which one created the best taste and texture for their ravioli filling. In this episode, Malaysia's aversion to tasting the filling prevented her from contributing to the discussion about which starch they should select for their ravioli filling. Notice that Malaysia did not want to hear about what it tasted like; she even balked at the suggestion they taste it. Ultimately, however, she tasted it (and liked it).

Episode 6.2 (3.18): Reflecting on the First Batch of the Potato Filling - Session 18 - Learning How to Use Starch Thickeners
Nina: "Yeah, it can be a little bit more watery, but not as watery as I stirred it up some more..."
CMG: "So maybe we should add a little less starch."
(0: 39: 25.9) Malaysia: "What it taste like?"
Nina: "It kind of tastes like mashed potatoes that's lumpy."
CMG: [returning with forks in her hands] "Alright, you gotta taste

it." [handing them forks]
Malaysia: "We gotta taste what?"
C: "That!"
Malaysia: "We just did!"
CMG: "Oh how did you like it?"
Malaysia: "I'm scared."
CMG: "What's wrong with it?"
Nina: "Nothing [holding fork in her hand], it's just a little…"
CMG: "A little chewy. We gotta make it less chewy."
Malaysia: "Stop please. Oh my God, aren't you scared? I'm asking..."
Nina: "It's not that nasty, I'm just…" [puts fork in her mouth]
CMG: [walks back over] "Alright, maybe…"
CMG: "Okay, so we're gonna try it again. We're gonna try it again - one time because we'll have to figure out if the chicken broth is making it kind of chewy. So we'll try it with water."
Nina: "No, if it's too much, because you know how it soaks in liquid, then it was like a lot of um…"
Malaysia: "Oooh, this stuff kind of good."
CMG: "So what do you think you should do?"
Nina: "I think we should put less, um, flour or cornstarch in there."
CMG: "Oh less - well we're not using cornstarch, what are we using?"
Nina: "Flour."
CMG: "What is it called? But it's not just flour…"
Malaysia: [putting some more in her mouth] "Potato flour."
CMG: "Potato flour, okay, okay. So how much do you suggest we use?"
Nina: "We used a half of a cup?"
CMG: "We used a fourth of a cup."
Nina: "I think we should use half."
(0: 41: 03.3) C: "Half, goes up, half makes it more."
Malaysia: "Ooooh, this is good!"

While this episode highlighted Malaysia's aversion to tasting food, it also highlighted that she had the power to overcome her aversion as well. Notice in this episode how Malaysia gradually warmed up to the idea of tasting it when she was not pressured, after Nina and Christina tasted it and said it was not bad. After tasting the potato filling, she could not stop eating it. In fact, Malaysia ended up liking the taste of the filling so much that she could not stop eating it long enough to participate in the decision-making process about how much starch to use.

In summary, Malaysia's aversion to touching and tasting foods prevented her from making her own observations about the tastes and textures of foods, and limited her ability to use this information in making decisions about appropriate types and amounts of starch to use. Since Malaysia lacked these firsthand experiences, she was limited in her abilities to make observations and to contribute to the decision-making process about what starches to select. However, these episodes also showed that when she was able to gain secondhand experiences, she was able to contribute and share her opinions and observations. Thus, once Malaysia was able to overcome her aversions, her interest was piqued.

In summary, because of Malaysia's unwillingness to taste and touch the foods, her ability to cognitively engage in the hands-on aspects of activities was limited to that which she heard others say when they reflected on their experiences during story construction and big-group discussions. It seemed that the limitations on Malaysia's tactile engagement did not allow her interests to be piqued or sustained.

6.2.2 Visual

Malaysia rarely engaged in the continuous-monitoring patterns that fostered the secondhand experiences so important for helping participants to supplement their firsthand experiences and gain exposure to other participants' working, which allowed them to have a more holistic view of what it took to prepare a recipe, and for particular phenomena to occur.

So the questions I have are as follows: What were Malaysia's visual experiences? What developed from those experiences and how, if at all, did they lead cognitive engagement?

6.2.2.1 Small-Group Visual Engagement Experiences

During the small-group activities, Malaysia did not engage in continuous monitoring of others and artifacts. Episode 6.3 highlights the scope of interruptions in her monitoring of others and artifacts during the recipe-preparation process. It also highlights her desire to chase after activities of greater interest to her during the recipe-preparation process. As a result of not taking the opportunity to continuously monitor others and artifacts as they were being prepared, Malaysia had limited ability to reflect on the process and engage in conversation about what went wrong in the preparation process, in hopes of identifying causes of the recipe changes.

Episode 6.3 took place during Session 16, the day of Malaysia's first small-group activity, which was also the first Choice Day for the Thickeners Unit. This group was composed of the facilitator, Malaysia, and Candyce. They chose to make a fruit tart with a pudding-based custard. Prior to this episode, Malaysia worked with the facilitator to come up with a plan for the texture of the pudding-based custard and to select the starches they believed would help them achieve that texture. This was achieved by using the KSI software results from the pudding experiments that Malaysia had missed. The pudding experiment was designed to introduce the participants to four different starches that produced different textures from chunky to slimy and different textures from liquid to paste-like thickness. Malaysia used the software to gain access to the findings of other groups. From those results, she proposed a starch that would best achieve custard filling that would retain its shape when fruit was placed on top of it and it was cut into slices.

In Episode 6.3, Malaysia and her group are making the filling using two starches: cornstarch (which she proposed) and arrowroot (which her fellow group member

Candyce proposed). This experience offered Malaysia her first opportunity to see how starches thicken. To this point, she had only seen the final results of different amounts of cornstarch used to thicken the strawberry pie filling, and read about the results of various starches used to thicken pudding. She had not seen the process by which these starches actually thicken. Even so, she shied away from watching the pot with the milk and starch mixture and engaged in other activities at the sink, despite the facilitators prompting her to monitor the pot.

Episode 6.3:
[JLK tries to get stove to turn on, Candyce holds pot. They move to the next stovetop.]
JLK: [to Malaysia] "You gotta stir."
Malaysia: "So we've got to watch it?"
JLK: "Somebody's gotta watch it."
Malaysia: "I'll watch it, Candyce."
[Candyce pulls up a chair to the stove and watches the pot while Malaysia and JLK, backs to the camera, are at the sink. Candyce stands and looks in. Candyce moves over to emptied green bowls, peers in, stirs a little with a spoon, and moves back over to the pot. It's not heating fast enough, so JLK goes to get the hot plate and places it between the two stoves. Candyce hands JLK the hot plate. Malaysia is at the sink not paying attention to this interaction. Candyce takes her seat again. Candyce picks up chips on table, puts them down, and peeks in drawer in the kitchen while sitting in her chair. Candyce walks around, comes back, peers in pot, bends over to look at burner, and walks around some more.] [Candyce puts top on milk. She says something inaudible, she moves with milk off camera.] [JLK comes over to the pot, Candyce quickly comes up, stands in front of the pot.]
Candyce sits back down in the chair, peers over across the room
Malaysia and JLK are not shown on camera, but JLK is- she's picking things up.
Candyce stands up: "It's steaming!" [She claps her hands together. The contents of the pot are finally heating up.]
[JLK goes over to look at computer. Candyce remains at the pot. Malaysia comes back over.]
JLK goes over to stir; Candyce leans in over the pot.
Candyce goes over to computer as JLK stirs.
Malaysia walks in between both of them.

Candyce: "It says... foam at the top." [Reports to JLK at pot]
Malaysia sits at big table
Candyce: [Goes back over to the pot]
JLK: "Okay, Malaysia! Moving on, what's the next thing?"
They all go back over to the computer. JLK at front of computer
JLK: "The next step says..."
[Candyce is standing behind Malaysia and JLK, but in between them, Candyce reaches in, leans in to get right in front of pot. They pour fruit tart custard from the pot into something else. Candyce pours, Malaysia stirs, JLK stands to side and directs.
They've poured mixture into the pot. JLK comes over to table and instructs Malaysia to keep stirring]
Malaysia: "I love..."
Malaysia: "It smells good."
Candyce off to side
JLK walks over to computer, Candyce walks with her
Candyce is stirring on hot plate
JLK comes over and is looking in, talking
Malaysia runs off to get something
JLK goes off
Candyce remains at pot
JLK: [to Candyce] "Keep stirring and I' m going to go do something."
[Candyce remains at pot stirring. Other girls [CTNY, AS, CHI] come over and look in pot.]
JLK: [comes back to the table] "Look what I found." [She brings over fruit.]

JLK [asks Malaysia]: "Do you want to cut some fruit?"
[Candyce continues to stir, JLK, Malaysia walks over to the table.
Candyce remains at stove, Malaysia and JLK go to table to get Malaysia cutting the fruit
Candyce stirs and looks over]
[Nina tells Malaysia it's time to go; Malaysia tries to find ways to stay.]
Candyce continues to stir.
Candyce hands off stirring to JLK
Candyce comes over to table with Malaysia, stands around
Malaysia asks Candyce if she wants to peel some fruit [I think] tells her to get a knife from over there [out of camera view]
Candyce comes back with a knife and begins cutting
JLK stirs, Candyce and Malaysia cut fruit. [TJ and Nina come over and look at what they're doing.]
JLK asks if either of them wants to take over stirring
Candyce: "I will! I'm not that good at cutting as you can see."
[Candyce takes over the stirring.]
JLK goes over to the fruit, tastes some of the fruit

Malaysia: “Strawberries sweet?”
JLK: “Mmm hmmm…”
Candyce: “I think it's done!”
[Candyce continues to stir the fruit tart custard filling. JLK is at computer. Malaysia is at the table. CHI comes over to look at Malaysia. Candyce and Malaysia get the pie shell out, JLK takes the pot and pours the filling in Malaysia comes over to look.]

Notice in Episode 6.3 that when Malaysia was offered the opportunity to stir the pot, she did not really want to do it, but when she discovered that it was a way to be engaged, she volunteered to do it. Then notice that when another participant volunteered to do it, Malaysia found something else to do. This was an example of how Malaysia did not engage in watching others' pattern, a frequent trend. Furthermore, it was the first opportunity Malaysia had to watch an artifact as it changed over time, but she did not follow through in observing those changes.

In this episode, the structure of the Choice Day activities also contributed to inhibiting Malaysia from continuously monitoring the fruit tart filling preparation process. Since the activity had two separate components that needed to be prepared- the fruit tart's pudding/custard filling and the fruit to decorate the top of the pie- participants could maintain full engagement in one component's preparation processes without concerns about the other component. Thus, Malaysia missed a number of opportunities to see changes in the fruit tart fillings brought about by the starches she and Janet had selected to achieve the desired texture.

Since Malaysia was so focused on the fruit-cutting component of the fruit-tart preparation process, she missed a number of opportunities to have secondhand experiences of visually observing what others were doing, and what changes the fruit tart custard filling was undergoing. In essence, Malaysia missed a firsthand application of her knowledge about starches, which was the focus of the activity to begin with. The fruit-cutting was merely the decorating process.

Furthermore, not having continuously monitored the process, and not having seen the phenomena initially, there was a major gap between what Malaysia heard and understood from the big-group discussions and the firsthand experiences with the recipe artifact and seeing the transition process. Thus, because Malaysia was not continuously monitoring the fruit-tart custard filling during the small group activities, she missed the opportunity to see the process by which the custard thickened and the important cooking phenomena and science phenomena this process contained. This gap resulted in Malaysia having to always rely on the conclusions that others had drawn from the activities, rather than allowing her to be an active participant in these discussions. Given her curious nature and ability to make connections between things, it was disappointing that she did not have this consistent experience in the program.

I speculate that since Malaysia missed the initial KSI experimental activities, she did not know the pudding might change in interesting ways because of the starch. That, coupled with the more active and creative process of cutting and arranging the food, meant that she missed another opportunity to have this interest sparked. In addition, since there were only two participants, the girls did not have to compete for something to do. Malaysia just chose the one activity that she found more interesting. She interacted a lot with mixing, cutting, and measuring ingredients. These experiences seemed to ground her and her stories of activity.

This group made the fruit tart pudding-based custard two sessions in a row. In neither session did Malaysia want to stir the custard for significant periods of times, so she did not she see the custard thicken. Thus, she developed a major gap in her understanding of what it takes to get starches to thicken and the amount of time it takes.

6.2.2.2 Big-Group Visual Engagement Experiences

Malaysia was far more visually engaged during big-group discussions. In particular, during the big-group discussions Malaysia often had one-on-one interactions and conversations with the facilitator, and these discussions sparked Malaysia's interest and cognitive engagement. In addition, the big-group discussion provided Malaysia with both the visual accessibility of other participants' interactions with artifacts and her own visual tracking of artifacts. She was not watching changes happening during these episodes, but she was able to see results of cooking and differences in results across groups. This seemed to pique her interest, focus her attention on important phenomena, and prompt her to make comparisons between artifacts (though this curiosity did not cause her to become more engaged during subsequent small-group activities).

Engagement in continuous monitoring manifested for Malyasia when all of the KSI participants were gathered around a table focusing together. During these times she monitored what was going on and became curious about what she saw. For Malaysia, these seemed to be the experiences that provided her with a way to participate, interact, and become more knowledgeable.

6.2.3 Verbal/Auditory (Listening to and Giving Verbal Cues)

Another major factor that impeded Malaysia's ability to attend to visually-interesting cooking phenomena was that during small-group activities, she missed a number of verbal cues meant to signal her attention. There were two types of verbal cues that inhibited her physical and cognitive engagement in activities: those that Malaysia apparently did not hear and those that she heard and dismissed. When Malaysia missed these cues, her interest was not piqued to the point of visually engaging in many of the opportunities ripe for her viewing. This was the case when making the fruit tart custard filling presented earlier in Episode 6.3 during Session 15.

<u>6.2.3.1 Missed Verbal Cues</u>

I use an excerpt from Episode 6.3 to highlight two occasions when Malaysia missed important cooking phenomena indicated by Candyce. The first one occurred when Candyce excitedly called out that the custard is steaming and Malaysia is not present. The second one occurred shortly after when Candyce was at the computer reading off what they should expect to see next. This time Malaysia was present and positioned in a way that afforded looking in the pot and checking the status of the custard. However, instead of looking in the pot to see what it looked like, she walked over to the table and sat down. This, in turn, had a negative impact on her ability to reflect on the recipe-preparation process and the changes in the custard. Furthermore, it limited her ability to reflect on potential causes of mistakes or unexpected results, because she had not observed the majority (or even snippets) of the recipe-preparation process over time.

Episode 6.3 (excerpt):
[Candyce sits back down in the chair, peers over across the room Malaysia and JLK are not shown on camera, now JLK is, she's picking things up]

Candyce: [stands up] “It's steaming!” [She claps her hands together because the contents of the pot are finally heating up.]
[JLK goes over to look at the computer. Candyce remains at the pot. Malaysia comes back over to the table.]
JLK goes over to stir, Candyce leans in over the pot
Candyce goes over to computer as JLK stirs
Malaysia: [walks in between both of them, however, she is not focused on what either one of them is doing]
Candyce: “It says... foam at the top.” [reports to JLK at pot]
Malaysia sits at big table
Candyce goes back over to pot
JLK: “OK,, Malaysia! Moving on, what’s the next thing?”
They all go back over to computer. JLK at front of computer
JLK: “The next step says...”
Candyce standing behind Malaysia and JLK but in between them, she reaches in, leans in to get right in front of pot
They pour pot into something else. Candyce pours, Malaysia stirs, JLK stands to side and directs.

In this episode, since Malaysia was not continuously monitoring the progress of the fruit tart custard filling or Candyce’s activities, she missed two verbal cues. Notice in this episode that Candyce gave two verbal cues that there were interesting things to observe. The first cue was that the pot was steaming, significant since the group was having problems with the stove burners and the hot plate. Malaysia missed this cue because she was not present. However, notice that when she returned, and the facilitator and Candyce were standing around, she went over to them but did not stay very long. Thus, nothing visually caught her attention. The second verbal cue Candyce gave was reading from the recipe what they should expect. In particular, she said aloud, “It says...foam at the top [reports to JLK at pot].” But instead of going to see what was happening in the pot, or engaging Candyce in conversation about what that meant, Malaysia sat down at the big table at the farthest position away from the pot where the facilitator and Candyce were working. I believe her positioning was based on where the chair was located, and thus, it was not indicative of her lack of interest in the activity.

The key thing to note from these two missed verbal cues is that the cues were meant to focus Malaysia's attention on what was going on with the artifact. Moreover, based on Malaysia's interest in participating it was surprising that she did not look at the recipe or inquire about what other ways there were for her to participate. Instead, Malaysia sat at the table until the facilitator tried to pull her back into the activity by bringing her some fruit to cut. This also happened when Malaysia was preparing the potato filling for the ravioli, when she just decided to sit down instead of watching the filling thicken.

Since Malaysia was working on another part of the fruit tart project, she did not often acknowledge the verbal cues that Candyce and the facilitators gave that signaled changes in the recipe. Therefore, I believe that because Malaysia was working on a different part of this project, and the other parts of the project did not necessitate her attentiveness to the verbal cues Candyce was giving inhibited Malaysia's cognitive engagement. Moreover, since the artifacts that Candyce was working with were not on the shared surface with Malaysia, they did not have persistent presence that would have facilitated Malaysia observing them while still doing her activity. Furthermore, the black metal pot did not lend itself to being observed across the distance that separated Malaysia from Candyce. Accordingly, the pot was closed to observation unless participants were directly above it, rendering it to have closed observational affordances.

6.2.3.2 Heard and Dismissed Verbal Cues

The second type of verbal cue that inhibited Malaysia's cognitive engagement were those that Malaysia did hear and acknowledge, but that she quickly decided she was not interested in engaging in. In particular, these verbal cues signaled school-related subjects, concepts, or tasks (e.g., science, ratio, and writing). I've included episodes that happened during both the small-group and big-group activities to highlight this pattern.

In Episode 6.4, Malaysia heard the word "ratio" and acknowledged that she did not want to engage in math-related concepts. Episode 6.4 took place during a big-group discussion meant to highlight that different amounts of starch in the same amount of water would result in a different starch-to-water ratio, and would lead to different textures and thicknesses of the resulting strawberry pie filling. Notice that as the conversation developed and the word "ratio" was not mentioned again, that Malaysia re-engaged in the discussion. However, as a consequence of her resistance to listening to the word ratio, Malaysia missed an opportunity to make a connection between the word and a real-world application of it. It was also clear that Malaysia was cognitively engaged in the discussion as she shared her understanding of the container with fewer starch granules being less congealed (24:32). Although her statement focused on the amount of water, she was reflecting more on the height/depth of the water given the container's contents, since each container had the same amount of water. The only reason she would have talked about the water's height/depth was because of the displacement caused by different amounts of Cocoa Puffs® in each of the containers.

Episode 6.4 (3.9): – Session 16 - Science Learning
C: “But what do you guys notice about looking at these four containers?”
Girls: “Some have a lot and some have a little.”
C: “But what about the ratio of water to starch granule?”
(0: 23: 55.1) Malaysia: “Oh ratio!”
Treeva: “RATIO! No more math.”
Malaysia: “I know right.” [Agreeing with Treeva who chimes in.]
C: “Remember, to each of them we added one cup of water. So what do you notice?”
Someone: “That all of them or that some fell into the water as they soaked.”
C: “What do you mean they fell into the water?”
Someone: “I mean the water [pause] got...they got.”
C: “You mean the Cocoa Puffs soaked up some of the water?”
Malaysia: “Yeah, they absorbed it.”
C: “Absorbed some of the water. Very good word, good word.”
C: [stirring the first container] “So what do you notice about this one? See this one kind of. I can stir it easily. And what do you notice? There is a lot more water in it, right?”
Girls: “yeah!”

24: 32
Malaysia: “The one with the less water is less [pause] congealed.”
C: “Right, so that way when you can, imagine that would help us to understand why our pie filling was kind of thin when it only had one and a half tablespoons of cornstarch.”
Malaysia: [still standing and looking at the demonstration and Christina talking]
C: “But as you start adding more cornstarch in it, what do you notice?” [Moving down the line of containers representing different amounts of cornstarch and water mixtures, she mixes the containers with a long mixing spoon.] “You notice the ratio of water to cornstarch starts to even out, and it starts to increase in thickness. As you go up and up, the same thing happens [placing her hand over the top of each of the containers on each utterance of "up"]. “So when you start getting to the point of so many starch granules to your water, it is hard to stir, and that is why it is thicker than the other ones with less starch granules.”

This pattern repeated itself a number of times when Malaysia heard verbal cues related to science, math, or writing. In Episode 6.5, notice that Malaysia again shied away from the word “science” when Christina mentioned the science note cards, which contained information on the two starch molecules they'd been learning about in the program: amylose and amylopectin.

Episode 6.5 (4.7): **Session 18 - Learning Science Underlying How Starch Thickeners Work**
(0: 27: 32.8)
CMG: "Thank you, and so Tammy got us pictures, [Malaysia looks up at CMG] um, that way we can see what's going on inside of our starches."
Malaysia: "Uh oh, science."
CMG: "Uh oh science? So, like what it's called, we just have, so these are amylose - amylose is the curly one like that, but they're really kind of straight. And these are amylopectin [points], they're the branched ones. And so when it's cold, nothing really happens. [Malaysia looks on] So that's when it's cold. Then when you start to heat it, the starch starts to absorb water. So what should we do? [to Nina who's measuring] You gotta fill it all the way up to the top. But should we put the starch in when it's cold, or should we put the starch in once it gets, once our um, mixture gets warm?"
Malaysia: "Put it in where…"
CMG: "There." [She points to pot on the stove]
Malaysia: "Um, once it gets heated."
CMG: "Why?"
Malaysia: "So it can absorb."
CMG: "I know, it's gonna absorb either way, but we just want to figure out which way are we gonna add it- before or after?"
Malaysia: "During."

Ironically, the facilitator did not mention the word "science" explicitly, but Malaysia was able to connect the notion that they were learning the science behind cooking with the facilitator's statement, which was repeatedly stated throughout the program. Despite her verbal renouncement of science, Malaysia was excited to learn science or math so long as it was not made explicit that she was learning it. While this was not a major detriment to her learning, since it did not completely inhibit her cognitive engagement, there was cause for concern that if the key science or math words were used continuously, she might have completely disengaged.

6.2.3.3 Verbal Cues that promoted Malaysia’s Cognitive Engagement

In the previous section, I highlighted the patterns in verbal engagement that inhibited Malaysia’s engagement. However, some verbal cues did advance Malaysia’s engagement in science discussions. In general, this was when she could not identify that the topic of the discussion was scientific in nature. Verbal cues that identified words Malaysia did not recognize were particularly interesting to her. She would ask what it meant and then continue to revisit a word by trying to use it in new situations.

In Episode 6.6, Malaysia was exposed to the word “congealed,” and the unfamiliar word sparked her interest. Initially, the sparked interest was the result of her thinking that the word was “made-up”.

Episode 6.6 (3.1): – Session 15 - Learning How to Use Starch Thickeners
Amber: “That one's firm [referring to?]. It's like congealed.”
Amber: “This one looks more like jelly, like [pointing to either the first or second pie] like…”
Angela: “What that mean?” ↓congealed
Amber: “Like you know how Jell-O ®…”
Amber: “You know how when Jell-O ® sets?”
Angela: “Mmmm hmmm.”
Malaysia: “Is that some word you made up?” [In mocking tone of voice]
Amber: “That means it's congealed.”
Amber: “It's like when something's set, and it won't move.”
Angela: “I thought Jell-o® jiggles.” [Starts bouncing, or dancing]
Amber: “You know what I'm talking about that. Like that.”
Amber: “Stuck together, and it's not loose.”
Tammy then provides another confirmation of what Amber says by offering another comparison and Amber selects one of the pies.

The word “congealed” became Malaysia’s favorite word to use and apply during her participation in the program. She used it to describe how she wanted the texture of the fruit tart pudding-based custard filling to come out. She also used it to define the texture she wanted for the potato-filled ravioli, and she used it as a contrasting texture to define how she wanted the cream sauce for that same ravioli (see Episode 6.16). She also used it to describe the texture of Nina’s nacho cheese dip in Episode 6.16

In Episode 6.1, the unfamiliar word is “spreadable”. Recall that Malaysia did not understand what it meant “to spread” when TLC asked her to spread the preserves. Upon not recognizing what it meant to spread, Malaysia asked Angela to demonstrate. These episodes highlight Malaysia’s interest and initiative to follow-up on words she did not understand.

In Episode 6.7, Malaysia had just gotten over her fear of tasting the foods and was now distracted by tasting the foods, while Christina and Nina tried to determine what amount of starch to use to get the ravioli filling’s texture right. In this episode, the word “conversion”, both a math- and science-related word, caught her attention, and pulled her back into the conversation. She knew her phone had a conversion application, but she seemed not to know what it means or what conversions are needed for cooking. Somehow, this mathematical term pulled her back into the conversation.

Episode 6.7 (4.8): Session 18 - Learning the Science Underlying How Starch Thickeners Work

CMG: “Now you like it! So, if we go online, and we look for conversions. [Nina reaches and picks up an ingredient package on the table and looks at it.] So should we keep the same amount of chicken broth -?”
Malaysia: “I got conversions on my phone.”
Nina: “One and - oh, huh?”

CMG: "We should keep the same amount of chicken broth?"
Nina: "No, we should put in how much it called for and a half."
CMG: "Well we, last time we put in a whole cup, and a whole cup gave us the amount that we needed
[Malaysia looking at phone]. So we should probably still put a whole cup, but we should - but you said reduce, the amount of star –…"
Malaysia: [holding up phone to CMG] "You can convert numbers in here!"
CMG: "It tells you how to."
Malaysia: "Convert."
CMG: "Okay, so convert –"
Malaysia: "What are we converting?"
CMG: "How, how many tea- tablespoons are in a quarter of a teaspoon?"
[Malaysia does something on phone.]
Nina: [looking at Malaysia's phone] "Um, two…"
Malaysia: "Never mind, it only got speed, temperature, area, volume, weight, length, and that's it."
CMG: [reading computer] "... tablespoons equal…"
(0: 42: 05.4)Malaysia and Nina playing and knock something over
CMG reports 4 tbsps. In a quarter cup, so they can reduce amount of potato flour
asks how much they should reduce it by
Nina: "Um, tell how much we want to put in there."
CMG: "Yeah, like how much should we put in there, because we think, because you're saying we should add less starch?"
Malaysia: "How much is it? One eighth?"
CMG: "One eighth? We have four tbsps."
Malaysia: "A tablespoon, two tablespoons."
...

The fact that the math-based word caught Malaysia's attention and she did not shy away from it was a break from her normal pattern. However, this break from the normal might have had more to do with the fact that Malaysia thought she had a feature on her phone that could help with conversion tasks. Unfortunately, the conversion application on her phone was not made for cooking measurements so she was not able to use it after all. But the combination of the verbal cue and her desire to contribute led her back into the conversation and decision-making process about how much starch to use to perfect the potato-filled ravioli. Notice that Malaysia was wildly off in her recommendations for the amount of starch they should use in the next iteration of the recipe as she suggested one-eighth of a tablespoon when the facilitator and Nina were talking about four tablespoons. Thus, this example showed how verbal cues could be used to pull participants back into conversations, but facilitators still needed to be there to get them back up to speed.

Malaysia demonstrated the same curiosity when she did not understand a concept inn Episode 6.8. In this episode, Malaysia just missed the beginning of an explanation about the relationship between the thickness of the strawberry pies and the amount of tablespoons of cornstarch used in the recipe. To explain this concept the facilitator, Christina, used pieces of Cocoa Puffs® cereal to represent starch granules. She explained that there are two molecular structures in the starch granule that cause the starch granule to absorb water and swell. I believe that Malaysia was able to understand the concept starch granules absorbing water from earlier parts of the explanation, as indicated in Episode 6.4. In Episode 6.8, I believe that Malaysia is checking her understanding of what part the Cocoa Puff® represents in the model of how starches work. So she asks the facilitator what the coco puffs represented and if it will swell in her mouth. This suggests that she was again monitoring her understanding and making connections between the given explanation and its component parts. She later returned to this understanding of the role of starch granules to absorb water when she reflected upon why they should not use a wet spoon to mix in the potato starch in Episode 6.18.

Episode 6.8 (4.2): **Session 16 - Learning Science Underlying How Starch Thickeners Work**
(0: 18: 18.4)
Janet: "Can we eat these (referring to the Cocoa Puffs® that each girl is holding)?"
Christina: "Yes, you can eat these."

(0: 18: 20.3)
Malaysia: Cocoa Puffs® are starch granules?"
Malaysia: if I put this starch granule in her mouth, will it swell?
Christina: no [Chuckles.]

In general, big-group discussions included a lot of terms and concepts that Malaysia did not understand. While she tended not to be attentive to experiencing science phenomena during small-group activities, when she was in a big-group activity and was not cooking, her desire to understand energized her. I believe that Malaysia remained engaged in the conversations and learning because most of the material interactions during big-group conversations were accompanied by verbal descriptions or references to material artifacts (e.g., food items store bought and/or prepared by participants).

This is evidenced by the fact that half of Malaysia's material interactions were accompanied by verbal references to states, processes, or general properties of materials in an abstract manner (e.g., "oozing", "jiggles", "smooth", "firm", "thick", "thin"). Each of these was grounded in a verbal reference to something physically present through naming the artifact directly (e.g., jelly and pie filling), or indirectly referring to something (e.g., "it", "that", "this", "those",).

In addition, I believe that the verbal references to culturally-relevant materials (e.g., cookies, sandwich cookies, jelly, Jell-O, jam, preserves) also gave Malaysia a way to connect especially given her aversion to tasting and touching new foods. Thus, there were equal numbers of verbal references to culturally-relevant materials that were both present and not present on the table in front of the group, as there were verbal references to artifacts used/prepared or a concept introduced previously in KSI (e.g., pudding, amylose and amylopectin, starch granules, strawberry pie filling, cornstarch), and gestural references (e.g., pointing, using bodily motions to denote ideas). Thus, since the majority of verbal references were grounded in physically present artifacts, verbal references served as the major affordance of the big-group conversations that promoted Malaysia's cognitive engagement.

In general, within the big-group conversations, there was a lot that participants were attending to, but the use of "verbal references to materials physically present in the environment" provided affordances for Malaysia to develop or refine her understanding of concepts. Thus, these codes highlighted the situated and distributed nature of the social and material interactions in KSI that facilitated learning, participation, and knowing in KSI. Thus, the material interactions/references provided a significant amount of resources for participants to develop a shared understanding about what it meant for foods to be thick, and a variety of properties of thickness.

6.2.3.4 Summary of Verbal Cues

From the episodes highlighted in the verbal/auditory engagement section, there were a number of verbal cues that inhibited Malaysia's visual and tactile engagement and subsequent sensory engagement. In particular, Malaysia did not exhibit the same amount of cognitive engagement in small-group activities as she did in the big-group activities. In the small-group activities she participated in, there were fewer verbal cues to attend to, and a great span of time between key verbal utterances between participants. Thus, it was easy to understand how they were missed; but since not too much was going on, one might suspect that a bored participant would have looked for any reason to find something to engage in. Thus, there must be other reasons why Malaysia, who was very cognitively and physically engaged in the big-group conversations, was not as cognitively engaged in the small-group activities.

In this section, I have shown differences between Malaysia's attention to and responses to verbal cues in the big-group versus small group interactions. On the one hand, I have identified two ways that failing to engage with verbal cues inhibited Malaysia's cognitive engagement during the small-group activities: (1) unheard verbal cues that signaled important opportunities to see the artifacts change and afforded opportunities to gain a firsthand experience seeing the phenomena of interest in context (Episode 6.3); and (2) heard and dismissed verbal cues about math, science, or writing that often repulsed Malaysia. However, I also highlighted that Malaysia was very attentive to verbal cues in the big-group discussions that signaled words she did not recognize or concepts that she did not understand. There was a noticeable difference in Malaysia's attention to verbal cues in big-group and small-group interactions. In contrast to small-group interactions, the verbal cues expressed during big-group interactions piqued Malaysia's interest, sparked conversations, and furthered her cognitive participation and active interest in artifacts.

6.2.4 Summary of Sensory Engagement Patterns

Malaysia's ability to cognitively engage in the hands-on aspect of activities that required participants to taste and touch artifacts was limited to what she heard others say when they reflected on their experiences. Thus, Malaysia's cognitive engagement often involved recounting the summaries of others' experiences that she had heard during the small-group activities and, more often than not, the experiences or explanations of others during the big-group discussions. Thus, it seems that the limitations on Malaysia's tactile engagement hindered her interests from being piqued or sustained. Furthermore, for a variety of reasons, she did not recognize the importance or interest in seeing changes happening to artifacts over time and did not participate in activities that would have afforded those observations. Accordingly, she was limited to what she could understand from seeing foods before and after they were prepared. Her interest was piqued by words she did not understand and by preparing something that she could take home. She was, however, able to understand in-depth explanations of how starches work that were grounded in material artifacts.

6.3 Social Engagement

In Section 6.2 of this case study, I established that Malaysia's sensory engagement was inhibited during the small-group activities, and that she missed out on many opportunities to gain firsthand and secondhand experiences with key artifacts and focal phenomena. This section aims to demonstrate the effects that Malaysia's inhibited sensory engagement played in inhibiting her from engaging in the kinds of social engagement patterns that would have promoted her physical and cognitive engagement in activities. I also aim to understand what types of social engagement were used in the absence of these sensory engagement patterns to position Malaysia, coordinate activities, ensure that the activity was being carried out correctly, and to make decisions about the direction of activities. Additionally, I aim to understand what effect this had on Malaysia's cognitive engagement. In addition, if some of the social patterns persisted, what afforded them, and to what extent did they persist?

6.3.1 Positioning and Activity Coordination through Recipe-Reading

During Enactment #2, different from during Enactment #1, facilitators worked with individual groups and often positioned participants and coordinated activities by asking participants to do different recipe preparation tasks. We (the designers of KSI) decided to manage activities this way during Choice Days because the recipes that were being prepared were quite a bit more complex than those prepared during Semi-Structured Days and during Choice Days in Enactment #1. The added complexity was in making a dish aesthetically pleasing (e.g., arranging fruit on top of it in a beautiful pattern) or making a dish with multiple parts, only some of which contained a leavener or thickener. This added complexity led to participants distributing cooking roles across parts of the recipes, and unfortunately, this resulted in some participants not being exposed to the firsthand experience of seeing interesting phenomena change. As discussed previously, Malaysia chose to cut the fruit for the fruit tart and therefore did not have experience seeing the custard thicken. Furthermore, she did not engage in monitoring the thickening as her team-mate was stirring. Nor did her team-mate always try to draw her in when an interesting change occurred, as she knew Malaysia was involved in doing another important activity. And, as illustrated above, when she did try to draw Malaysia in, Malaysia did not always attend to the verbal cue; it was not relevant to tasks the participant was working on. This was common among the teams of participants in Enactment #2 and not simply due to Malaysia's way of engaging. Malaysia's experience shows the effects of this way of organizing small-group activities.

6.3.1.1 Positioning

Malaysia's group did not engage participant driven positioning and activity coordination during the small-group activities. However, I did see that Malaysia was receptive to opportunities to perform recipe preparation tasks. This attentiveness during small-group activities generally came from the facilitator's asking her to execute a particular task. To highlight this pattern, I want to revisit Episode 6.3, which was characteristic of the majority of small-group social interactions in this group. In this episode, as in most of their interactions, this group did not talk socially; for the most part, they stuck to performing their tasks. When Malaysia worked in other groups, she was markedly more social, but these positioning patterns persisted. While the other participant, Candyce, read the recipe to herself and executed the instructions, Malaysia did not. She waited for instructions. Recall from Episode 6.3, Excerpt #1, that Candyce read the recipe aloud, but Malaysia did not shift her participation in any way. In Episode 6.3, Excerpt #1, Candyce was trying to understand what was next and when the custard would begin boiling, since she had already noticed it steaming. Though Candyce was engaging in recipe reading, Malaysia missed this verbal cue.

Episode 6.3, Excerpt #1:
[Candyce puts top on milk. She says something inaudible, she moves with milk off camera.] [JLK comes over to the pot, Candyce quickly comes up, stands in front of the pot.]
Candyce sits back down in the chair, peers over across the room.
Malaysia and JLK are not shown on camera, now JLK is, she's picking things up.
Candyce stands up: "It's steaming!" [She claps her hands together. The contents of the pot are finally heating up.]
[JLK goes over to look at computer. Candyce remains at the pot. Malaysia comes back over.]

JLK goes over to stir; Candyce leans in over the pot.
Candyce goes over to computer as JLK stirs.
Malaysia walks in between both of them.
Malaysia: [walks in between both of them, however, she is not focused on what either one of them is doing]
Candyce: "It says... foam at the top." [Standing at the computer reports to JLK at pot]
Malaysia sits at big table.

Notice that while Candyce's recipe reading engaged the facilitator, who moved over to look at and stir the custard in the pot, Malaysia did not respond. Thus, this was a missed opportunity to experience the changing phenomena at intermediate increments. Malaysia was not listening. What would have caused her not to listen? Some reasons include: (1) a possible lack of interest (though very unlikely because she was a curious girl); (2) a visual distraction caused by something else, possibly based on the direction she was facing; and (3) an inability or unwillingness to hear what was going on.

Or perhaps because the facilitator was a major presence in the group, Malaysia did not realize the opportunities she and her group member had to organize the activities. Perhaps she was assuming a role more like in a classroom with a teacher in charge of at home with a parent in charge. Episode 6.3, Excerpt #2 shows the role that the facilitator played when the girls were not themselves assuming responsibilities or taking on roles. The facilitator highlighted the tasks that were available for them to do, suggesting that stirring the pot was something they might consider doing when she said, "You've gotta stir!" and "Somebody's gotta watch it." At the point, Malaysia realized this was an opportunity to participate, and she volunteered to watch the pot. But when Candyce joined her, she assumed Candyce was taking on that role and moved on to take on another one. There was another task to do, and Malaysia and the facilitator moved onto other recipe preparation tasks, leaving Candyce at the pot while they went to the sink. Candyce became the de facto pot stirrer for the next two sessions and was rewarded with an opportunity she had not had in the previous semi-structured experiment sessions - to feel the starch thicken the liquid. Unfortunately, Malaysia did not get to experience this.

> **Episode 6.3, Excerpt #2:**
> **[JLK tries to get stove to turn on, Candyce holds pot. They move to the next stovetop.]**
> **JLK: [to Malaysia] "You gotta stir."**
> **Malaysia: "So we've got to watch it?"**
> **JLK: "Somebody's gotta watch it."**
> **Malaysia: "I'll watch it, Candyce."**
> **[Candyce pulls up a chair to the stove and watches the pot while Malaysia and JLK are at sink doing something else**. Candyce stands and looks in. Candyce moves over to emptied green bowls, peers in, stirs a little with spoon, and moves back over to the pot. It's not heating fast enough, so JLK goes to get the hot plate and places it between the two stoves. Candyce hands JLK the hot plate. Malaysia is at the sink not paying attention to this interaction.]

Episode 6.3, Excerpt #3 also shows the facilitator positioning Malaysia, by attempting to pull her back into the activity. Notice that the facilitator called Malaysia's name and asked, "What's the next thing?" In this way the facilitator was aiming to position Malaysia to become more actively engaged in the activity. In response, all of the group members gathered around the computer as the facilitator read the recipe aloud. The three of them then worked together to coordinate pouring and mixing the mixture in the pot. After that, however, Malaysia then walked away from the table while the facilitator and Candyce talked at the pot.

Episode 6.3, Excerpt #3:

[Candyce goes back over to pot from just reading the recipe from the computer.
Malaysia remains sitting at the table]
JLK: "OK, Malaysia! Moving on, what's the next thing?"
They all go back over to computer. JLK is at front of computer.
JLK: "The next step says..."
[Candyce standing behind Malaysia and JLK but in between them, she reaches in, leans in to get right in front of pot. They pour pot into something else. Candyce pours, Malaysia stirs, JLK stands to side and directs. They've poured mixture into the pot.
JLK comes over to table and instructs Malaysia to keep stirring.]
Malaysia: "I love..."
Malaysia: "It smells good."
[Candyce off to side]

Furthermore, notice that after the facilitator read the recipe step aloud, all three of the participants got involved in the activity by pouring the pot's contents into another receptacle. Notice again that the facilitator was coordinating the activity by telling Malaysia to keep stirring. Malaysia then proceeded to make an observation about the pleasant aroma. "It smells good." Also notice that Candyce, who had been actively engaged in stirring the pot, was now pushed to the periphery by Malaysia, who was now stirring the pot. Overall, this episode highlights the noticeable lack of agency on the part of the participants to keep the activity moving and way that the facilitator took on the role of a coordinating the activity of the group. The participants' lack of agency may be due to the participants falling into the familiar adult-to-child power structures that they have become accustomed to.

While it may be argued that Malaysia was not interested or did not want to participate, during this session (as well as subsequent sessions), she was the last participant to leave and was always negotiating for extra time to complete the recipe preparation process. This disparity suggests that there may have been something inhibiting the way she was participating. Furthermore, notice that once Malaysia was engaged, she was vocal in her observations of the fruit tart custard filling ("It smells good"- Episode 6.3, Excerpt #3). This opportunity to stir was short-lived, however, once Candyce took over stirring the pot and Malaysia left the group's workspace. Notice in Episode 6.3, Excerpt #4, that Malaysia is not vocal at all and actually leaves the work space.

Episode 6.3, Excerpt # 4:
JLK walks over to computer, Candyce walks with her [The computer has the recipe on it.]
Candyce is stirring on hot plate
JLK comes over and is looking in, talking
Malaysia runs off to get something
JLK goes off
Candyce remains at pot

Notice that when the facilitator walked to the computer, Candyce walked to the computer as well, trying to figure out what she could do. One of the key things to notice about this episode was that Malaysia missed two opportunities to get cognitively engaged. First, she missed the opportunity to walk over to the computer and see what the next step was, and to engage in the conversation Candyce and the facilitator were having at the computer. Second, she missed the opportunity to engage in the conversation the facilitator and Candyce were having when they returned to the pot.

Episode 6.3, Excerpt #5 shows the role that the facilitator played in positioning Malaysia by trying to pull her back into the activity for a second time by going to get fruit and offering her an opportunity to cut it.

Episode 6.3, Excerpt #5:
JLK: [to Candyce] “Keep stirring and I’ m going to go do something.”
[Candyce remains at pot stirring. Other girls [CTNY, AS, CHI] come over and look in pot.]
JLK: [comes back to the table]: “Look what I found.” [Bringing over fruit]

JLK [asks Malaysia]: “Do you want to cut some fruit?”
[Candyce continues to stir, JLK, Malaysia walks over to the table. Candyce remains at stove, Malaysia and JLK go to table to get Malaysia cutting the fruit Candyce stirs and looks over.]

The fruit cutting was the beginning of the end of Malaysia’s social engagement, as it now completely separated Malaysia from the rest of the activity. The key thing I want to note is that Malaysia was not cutting fruit before, so it is not clear why she allowed herself to miss out on the other cues.

Episode 6.3, Excerpt #6 demonstrated that Malaysia, for the first time, offered Candyce an opportunity to participate in the activity that she was engaging in, fruit cutting. This opportunity became available only because Candyce had been relieved from the stirring by the facilitator, and had been milling about the table and the pot wondering what she could do. Malaysia noticed this and invited her to cut fruit.

Episode 6.3, Excerpt #6:
[Nina tells Malaysia it's time to go, Malaysia tries to find ways to stay.]
Candyce continues to stir.
Candyce hands off stirring to JLK.
Candyce comes over to table with Malaysia, stands around
Malaysia asks Candyce if she wants to peel some fruit [I think], tells her to get a knife from over there [out of camera view].
Candyce comes back with a knife and begins cutting.
JLK stirs, Candyce and Malaysia cut fruit. [TJ and Nina come over and look at what they're doing.]

Recall that in all of the Episode 6.3 excerpts, while Candyce was stirring the pot, she made herself open to observe what others were doing around her. She was looking at the table, sink, or computer where others were working. Malaysia, however, did not engage this way. The facilitator tried to engage her, but it was difficult. Finally, the facilitator was able to engage her in cutting the fruit. However, Malaysia's engagement in cutting the fruit did not position her for later cognitive engagement.

Episode 6.3, Excerpt #7 shows a shift back to what we'd seen before, with the facilitator's offering an opportunity for a participant to do something. This time, we see Candyce, not Malaysia, volunteering to stir the custard. Since Candyce had been stirring the pot for the majority of this activity, it was not surprising she had a vested interest in seeing the entire thickening process take its course, while Malaysia did not.

At the end of the episode, however, we do see Malaysia engage when Candyce announces that the custard filling is done. Malaysia, recall, is quite interested in taking food home to her family. Furthermore, recall that in Excerpt #6, Malaysia was asking her cousin Nina (who she was going home with) for more time so they could finish preparing their fruit tart. Thus, it was not surprising that Malaysia jumped up and got the pie crust so she could make her personal-sized fruit tart and take it home.

Episode 6.3, Excerpt #7:
JLK asks if either of them wants to take over stirring.
Candyce: "I will! I'm not that good at cutting as you can see." [Candyce takes over the stirring]
JLK goes over to the fruit and tastes some of the fruit
Malaysia: "Strawberries sweet?"
JLK: "Mmm hmmm."
Candyce: "I think it's done!"

[Candyce continues to stir. JLK is at computer. Malaysia is at the table. CHI comes over to look at Malaysia. Candyce and Malaysia get the pie shell out, JLK takes the pot and pours it in Malaysia comes over to look.]

These seven excerpts from Episode 6.3 highlighted that in the absence of the sensory engagement patterns of continuous monitoring and attending to verbal cues, and possibly because of the role the facilitator was playing, patterns of positioning and activity coordination were inhibited. This, in turn, caused the facilitator to continue to engage in activity coordination and participant positioning when she found the participants to be inactive.

However, I claim that the major factor that seemed to lead to the failure of participants positioning themselves and coordinating the activity was the structure of the activity – the fact that it had parts to it that fostered involvement in activities that inhibited first-hand engagement with phenomena and continuous monitoring and discouraged collaborative recipe reading and announcement of intermediate results. The role that the facilitator played was a direct result of the activity structure. This suggests that activity coordination and positioning are interrelated. In the case where participants already had something to do, because a facilitator had highlighted different tasks they could do, participants never had to take on the agentic role of trying to position themselves. Because they were working on different parts of a recipe, they were deprived of having to compete for a turn[3].

6.3.1.2 Activity Coordination

The Episode 6.3, Excerpt #7 can also be used to illustrate a pattern of activity coordination with Malaysia's group. Here the complexity of the recipes suggested splitting preparation activities into two components. Each participant took on a role and followed it through to completion independently. If another person picked up the role, the others did not watch.

Recall in Episode 6.3 that Candyce stirred the pot while the facilitator and Malaysia worked at the sink. Shortly after, Candyce and the facilitator stood over the hot plate trying to determine if it was going to work. Once they got the hot plate working, Candace stayed with it as the facilitator and Malaysia did something else. Then, the facilitator went back to the workspace and went to the computer to look at the recipe. Then, when Malaysia went back to the workspace, she stood between the facilitator at the computer and Candyce at the hot plate, said nothing to them, and then sat down at the big table. However, there was a brief moment when the participants were working together to

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[3] In discussions later, we realized that facilitators did not mean to take over but like JLK, they did when participants were not taking initiative. In fact, we had anticipated the need to provide more guidance as the recipes were getting more complicated at the end of Enactment #2 than they had been in other sessions. The guidance was needed because we only had an hour and a half for each session, and some of the recipes required significant preparation and cooking time.

pour and mix something in the fruit tart custard filling they were cooking. However, this was short-lived, as Candyce and the facilitator went over to the computer to see what else to do, while Malaysia stayed at the pot stirring until they went back, and then she left. Later, Candyce continued to stir and watch the pot while Malaysia cut the fruit. Then, there was a brief moment when they worked together again, once Malaysia had invited Candyce to cut the fruit.

This characterized the "split and switch" pattern that this group used as a means of activity coordination. While Malaysia was actively involved in both the planning of the desired texture of the fruit tart custard filling (she selected the starches she believed would achieve those results) and the initial measuring and mixing process, she was for the most part very disengaged from the cooking process, except for the brief episodes highlighted here. Thus, Malaysia often involved herself in aspects of the recipe preparation process that did not give her direct experience with seeing it thicken, and she rarely responded to others when they highlighted this change in state, for example, by getting up and going to look, or even stirring it herself. Rather, she regained active engagement with the filling at the end when they were assembling and decorating the dish.

Episode 6.3 is an example of centralized activity coordination. Notice that the facilitator identified the different tasks and roles available for the participants. Thus, Candyce for the next two sessions became the de facto pot stirrer and was rewarded with the opportunity she had not had in the previous semi-structured experiment sessions to feel the starch thicken the liquid. Candyce discovered differences in the two variations of the fruit tart custard filling, while Malaysia was focused on cutting the fruit and decorating the fruit tart. As a direct result of infrequent exposure to the custard preparation process, and non-acknowledgement of the verbal cues that signaled changes in the custard's texture, Malaysia did not contribute to the conversation about what had happened between the two fillings they had made.

Thus, it appeared that central activity coordination stunted the participants from engaging in activity coordination patterns like recipe reading and positioning that seemed to promote cognitive engagement in Case Study #1, Chapter 5. In addition, the activity structure seemed to make activity coordination and positioning null and void as there were too many subtasks that could be performed independently of one another. Worse yet, the number of subtasks corresponded with the number of participants who were available to perform them. Thus, in this group, since there were only two people, and the recipe had two distinct subtasks that facilitated long periods of engagement and could be performed independently, there was no reason for the participants to talk with one another, or to care what the other one was doing. Thus, it was very rare when the participants were sitting idle looking for something to do. Whenever Malaysia was sitting idly, the facilitator was always there to pull her back in so she did not stay that way very long. It was not clear how long Malaysia would have sat idly had the facilitator not been there.

6.3.1.3 Summary of Participant Positioning and Activity Coordination

Overall, without continuous monitoring of artifacts and others, heeding verbal cues, and activities that required interdependent materials, Malaysia did not have a need to position herself or to coordinate the activities. In addition, it is clear that without engagement in these social engagement patterns, she lacked knowledge of the recipe preparation process, which seemed to be important for written and oral reflection. As we move in to the next two sections, notice that since the girls did not engage in positioning and activity coordination, they also did not engage in a culture of sharing and collaborative decision-making which were important for helping participants cognitively engage in the small-group activities.

6.3.2 Culture of Sharing and Collaborative Decision-Making

While Malaysia did not always engage socially in the small-group activities, she did engage in information sharing and collaborative decision-making during the big-group activities. In particular, this took the form of listening to participants from other groups tell stories of how their foods had been prepared and reviewing the artifacts from previous activities. However, because Malaysia did not participate in the aspects of the small-group activities that would have allowed her to experience scientific and cooking phenomena, she was limited in her own abilities to really add to the discussion of the effect that starches had had on her group's recipe because she had been more focused on cutting the fruit than in the preparation of the custard. In the absence of both the sensory and social engagement patterns, Malaysia's small-group experiences were not grounded in seeing the artifacts develop, thus she was limited to sharing details she'd overheard Candyce convey or through reading the story Candyce had written. Moreover, Malaysia was unable to use this information as a resource to think with because she was limited in her scope of knowledge. She only knew what happened in the beginning, and the outcome, and lacked details about the recipe preparation process.

Episode 6.8 highlights Malaysia' active engagement in planning of the fruit tart recipe her group prepared. In Episode 6.8, we see that Malaysia was actively engaged in the planning process while Candyce is absent from the conversation. Notice that Malaysia engages in conversation with JLK by offering suggestions about the taste and texture they want their fruit tart filling to have.

Episode 6.8: – Session 16 - Learning How to Use Starch Thickeners

JLK: [off camera] "OK, so let's see what we are supposed to do, OK?"[Walking back onto camera and to the counter near the computer and looks down at a small stack of papers] "First of all, what…? [pause] [Malaysia and Candyce come into view of the camera and circle around Candyce.] We are supposed to look at this." [Inaudible, but picks up the papers]
JLK: "Think in terms of... [Inaudible but bits and pieces suggest that they are talking about all the things they want their tart to turn out like in terms of five senses] Smell." [Sniff]
Malaysia: "Congealed."
JLK: "Sweet."
JLK: "We want it to look?" [Using descriptive words]
Malaysia: "Moist."
[Malaysia and Janet continue to discuss how they want it to turn out. They talk about using descriptive words, however, most of this exchange is inaudible.]
Malaysia: "Are we making two of them?"

While Malaysia was actively involved in the planning, she lacked engagement in preparation of the actual fruit tart filling. Thus, she missed a number of opportunities to see the phenomena happen firsthand or to observe them secondhand. This lack of participation later became problematic for when it came time to trouble-shoot what made the second fruit tart filling thicker. In particular, Malaysia was unable to contribute and did not want to participate in the conversation to hear what had happened. This was most evident in Episode 6.9, when the facilitator tried to bring Malaysia into the discussion about what had happened to the second fruit tart filling that had not come out as expected. In general, the facilitator tried to bring everyone into the conversation, but participants could leave and do other things.

Episode 6.9: – Session 16
Malaysia: [sitting with her back to JLK and Candyce as they are talking]
JLK: [is at the counter with Candyce and turns around to Malaysia] "So, Malaysia?"
Malaysia: "Huh?"
JLK: "What could we tell…that we did last week?"
Malaysia: "That the um, filling is more … thinner or thicker…?"
Candyce: "Thicker."
JLK: "Oh yeah… [Goes to add at the computer]. We don't know why."
Candyce: "But we…let it stay on there longer, and we might've added more arrowroot."
JLK: "I don't think so."
Candyce: [stirs the pot]
JLK: [walks around, grabs the spoon, gets filling out of pie]
Malaysia: [walks around to Candyce and JLK]

Thus, in the absence of continuous monitoring, the girls did not engage in a culture of sharing and collaboration; similarly, the girls did not gain experiences important to learning about the recipe preparation process through positioning themselves to be actively engaged in the coordination of the activity. Rather, the girls engaged in a culture where everyone did his/her role, and got back together at the end, either to individually write their stories or to collectively write the story in a "staple together" fashion. Recall Episode 6.3, where Malaysia and Candyce took turns doing recipe preparation tasks without observing each other for prolonged periods of time.

Furthermore, decisions were often made between the facilitator and one participant. This created a discontinuity between what participants planned to do and what was actually done. This was particularly the case for Malaysia who was actively engaged in the planning and selection of the ingredients her group should use to make the fruit tart filling of their desired texture specification but did not actively participate in the actual preparation of the fruit tart filling. Thus, discontinuous participation limited the opportunities for participants to make significant connections between the plan, and what it took to actually implement the plan. As a result of Malaysia's discontinuous participation, she was unable to see the phases the milk and thickeners went through in order to thicken the fruit tart filling to gain an understanding of the role that the thicker she chose played in thickening the filling. Additionally, discontinuous participation limited Malaysia from seeing whether the plan worked or not and why. For example, the second time the group made the fruit tart filling the texture did not come out as expected and Malaysia wasn't able to participate in the conversation between Candyce and JLK when they were trying to trouble shoot the preparation process to determine why the texture came out differently the second time

In summary, the inhibiting social engagement patterns are "split and separate" activity coordination, individually and facilitator-guided decision-making and trouble-shooting, and facilitator appointed participant positioning. Despite the facilitator's effort to pull Malaysia into conversations and to position her in more active roles, Malaysia was limited in what she was able to take away from the small-group interactions as she was not actively involved in them. This suggests that facilitation cannot always overcome some key habits that inhibit social engagement.

This also suggests that the one role facilitators should not take on is the role of activity coordinator. They should not be coordinating the small-group activities because this nullifies participant autonomy. In addition, there is a constraint that needs to be balanced when participants are working on some of these more open-ended activities, since they do need sufficient structure to allow participants to operate autonomously, but not so much that they have no need to see what other participants are doing.

6.3.3 Catching and Correcting Mistakes and Making Sure they are "Doing" the Right Thing

In the absence of continuous monitoring, a culture of information sharing, and collaborative decision-making, mistakes were not caught very easily. Rather, detection of mistakes occurred only by a single individual, Candyce. Candyce detected these mistakes because she acquired an expectation of how the artifacts should develop and what artifacts should look like at the end. However, because of the "split and switch" practice of activity coordination, Candyce's experiences were not shared by Malaysia. Thus, Malaysia only had access to the knowledge and observation that the outcomes were different, with no reasoning experiences to help her understand what had caused the differences. This resulted in Malaysia's inability to trouble-shoot the question of why the two fruit tart custard fillings had come out differently when Candyce and the facilitator were discussing possible causes.

Episode 6.10 highlights what happens when mistakes were not caught right away and instead discovered later. In this episode, Candyce recognized that the two fruit-tart fillings they'd created over the two sessions, Sessions 16 and 17, had different consistencies, and alerted the facilitator to the difference, wondering aloud what might have caused the problem. Notice Malaysia's absence from this conversation. During this conversation, Malaysia was sitting at the table cutting fruit.

Episode 6.10, Session 17:

[Audio-only]

Candyce: “It's supposed to foam at the top right? [Some time passes]It's supposed to foam at…” [Inaudible]

[Audio and Video]

[Malaysia is seated at the table cutting fruit.]

JLK: [JLK walks around with pot and spoon in hand.] “Look at it, it's a different texture than last time.”

Candyce: [Candyce looks into pot.] “I think…” [Inaudible]

JLK: [pause] “Looks thicker. That's good, it's gotta… [inaudible] together.” [Makes axing motion with hand as if to specify that the thickness is good so that it will hold together when they cut it. This supports the desired texture they were aiming for.]

Since Candyce had been continuously monitoring the fruit tart custard filling, she was able to recognize that the second fruit tart filling was not developing the way that the first one had. At the beginning of this episode, she’d recalled aloud that the custard was supposed to foam and when it did not, she commented about it not foaming for a second time. This caught the facilitator’s attention as she was walking over to the pot, and she subsequently acknowledged the texture difference. Although Candyce’s statements were not completely audible, you could see that she was beginning to wonder what happened.

While this discussion was going on, Malaysia did not take a look at the custard, nor did she participate in this discussion, but she continued to cut fruit. Recall that this was what she had done the previous week, when Candyce was giving verbal cues about the custard steaming, and reading the recipe about the need for it to foam. Thus, Malaysia missed a second opportunity to observe the thickening custard, and so she did not participate in the discussion about what had caused the second version to be different from the first. In addition to Malaysia’s inability to participate in the conversation, the scope of the group's collective reflection on the causes of the change in the filling was inhibited. Recall that continuous monitoring allowed the boys to collectively reflect on the changing foam height in the yeast air-balloon water bottle. This collective reflection was fostered by the observations each boy had made while they were preparing the pizza dough and occasionally glancing at the water bottle. Thus, I would have expected, notwithstanding Malaysia's cutting of fruit, that she would still have been able to see the changing custard filling over the two versions, and that she would have been able to participate in the conversation about its possible causes.

Episode 6.11 highlights the extent to which Malaysia had not been paying attention to the ongoing conversation between Candyce and the facilitator, and was still unable to participate. Notice that when the facilitator tried to pull Malaysia into the conversation about what to write in the story, Malaysia was at a loss in terms of articulating the differences between the two artifacts. Also notice the way that Candyce began to raise additional reasons the custard filling might have come out differently.

Episode 6.11:

JLK: "OK, I don't know so, I mean... " [JLK talks with Candyce at computer while Malaysia sits behind them at the table cutting fruit.]

JLK: "So, Malaysia."
Malaysia: "Huh?"

JLK: "What could we tell... that we did last week?"
Malaysia: "That the um, filling is more... thinner or thicker...?"
Candyce: "Thicker."
JLK: "Oh yeah. [Goes to add that to computer.] We don't know why."
Candyce: "But we... let it stay on there longer, and we might've added more arrowroot."
JLK: "I don't think so."

This episode shows that based on the different experiences the facilitator and Candyce had with the custard fillings, they disagreed about the potential cause(s) of the thicker second version. Although they both had experiences mixing and monitoring it, Candyce had spent the majority of her time monitoring it, while the facilitator had had more sporadic observations of the filling. Thus, Candyce was able to recall that the custard filling had been cooked for a longer time. Then, she speculated that they might have added more arrowroot, one of the starches they'd used to thicken the mixture. However, the facilitator disagreed without much explanation until later, when Candyce insisted the cause was the increase in the amount of arrowroot used.

This episode shows that Candyce was very engaged cognitively, and that it bothered her that something had occurred to cause a difference between their two custard fillings. Candyce's suggestion that it might have been arrowroot was an acknowledgment of the role that starches played as a thickening agent. In addition, this episode suggests that Candyce chose arrowroot as the cause (of the two starches they had used) because she was recalling her previous experiences with arrowroot. On Week 11, Candyce's group had made pudding, and had measured the thickness of the pudding with a viscometer, discovering that after more than five minutes, the pudding was so thick it would not go through the opening.

In Episode 6.12, notice that Candyce continued to try to understand what might have caused the differences, and that she and the facilitator still did not agree on a cause.

Notice that Malaysia was now participating in the activity, but she was still did not substantively contribute to the conversation.

Episode 6.12:
[JLK, Malaysia, and Candyce talk about watching for something after Candyce made a comment.]
Malaysia: [Takes pot and pours filling into big pie]

Candyce: [looks on]
JLK: [to Candyce] "Do you want to taste the whisk?"

Candyce: [tastes] "I wonder what happened [pause, places her hand on her hips] Maybe it was slightly more arrowroot."

JLK: "I know we didn't add more." [Inaudible]

Candyce: [looks on as they pour] "It's smoother."

Malaysia and Candyce: [They both look on intently as JLK spreads filling in pie]
Malaysia: [tastes some filling with her finger]
Candyce [reaches for emptied pot and tastes]

[They discuss what it tastes like.]

In this episode, Candyce tasted the filling and suggested that maybe it was "slightly" more arrowroot. This time, the facilitator backed up her reason for thinking that the cause was not the increased amount of arrowroot. These episodes highlighted the role that the participants' increasing amount of continuous watching had in creating more of a vested interest in understanding the cause(s) of the unexpected results, and in affording more opportunities to connect and draw upon previous experiences. Furthermore, it highlights that the continuous watching of artifacts and others provided participants with different shared experiences they were able to draw upon to discuss potential causes for these unexpected results. Thus, since Malaysia had very few experiences monitoring the custard filling, she was only able to express the fact that there were differences, and that the cause was unknown.

As a result of her interest in understanding what had happened to the fruit tart custard filling the second time, Candyce decided to document it in a story. At this point, the group had decided to thin out the filling by heating it again with a little milk. Episode 6.13 highlights this transition:

Episode 6.13: Session 17
Candyce: "That looks [?]"
Malaysia: [She reaches in pot and plays around with fingers in pot]
Candyce: "It's good but it's rubbery." [She walks around to computer.]
JLK: "Do you want to write a story or explanatoid?"
Candyce: "Alright, we should say… [Inaudible] …one is between the two." [Inaudible]
JLK: [volunteers to write for Candyce]
Candyce: "OK, you can take notes so I can watch the filling and see something."

In this episode, Candyce moved from making observations about the texture of the pudding, to wanting to write a story about the differences in textures between the two fillings. Thus, Candyce walked over to the computer to write her story. In the process of composing her story, the facilitator volunteered to be a scribe so that Candyce could watch the filling. Notice that Malaysia was now having firsthand interactions with the custard filling, but she did not make any observations about the taste or texture.

Malaysia did not contribute much to the story-making process, except to say that her father liked the fruit tart she had taken home the week before. Episode 6.14 highlights the extent to which Malaysia was able to contribute to the story.

Episode 6.14: Session 16
JLK: “Do you want to say, do you want to talk about how everybody liked it?”
Malaysia: “But we don't know how they liked it.”
Candyce: “Like, they could've lied to us.”
JLK: “Yeah, except for they told Tammy they liked it...”
Candyce says something [can't hear]
Candyce tells JLK something, Malaysia walks up between them.
[They're all at computer talking. I think I hear JLK talking about making a new story - they are talking about who told them it was good.]
Malaysia: “... it was good, my Daddy ate some... they talked about the texture...”
Candyce stands off some, but looks over at them.

In summary, because of the “split and switch” practice of activity coordination, and the absence of continuous monitoring of others and artifacts by Malaysia, Candyce’s experiences were not shared by Malaysia. Malaysia’s lack of shared experiences prevented her from reflecting with her group about the cause(s) of the unexpectedly thicker fruit tart custard filling results. Thus, Malaysia was unable to contribute to or benefit from the cognitive dissonance Candyce experienced over the thicker custard filling. Moreover, the group was unable to have a collective conversation about the artifacts and their development. Furthermore, they were had less resources to catch mistakes or prevent mistakes.

6.3.4 Summary of Social Engagement

In this section, I have aimed to understand what types of social engagement participants engage in, in the absence of the sensory engagement patterns that seemed to be vital components of participants engaging in these social engagement patterns and the ways they promoted participants’ cognitive engagement. Additionally, I aimed to under what circumstances participants engaged in these patterns and to what extent they were able to engage in these patterns. I found that the facilitator took on the role of positioning participants. Thus, instead of participants' continuously monitoring activities to find out what was coming up next, and acquiring the materials to gain an opportunity to perform the next step, participants in this case were told what activities were available, or asked to do certain activities. In addition, since the group was composed of only two participants, there was often enough for participants to work on for long periods of time. This was possible because the group was so small, and because the activity structure of the Choice Days consisted of several parallel recipe preparation processes, all independent of one another.

In addition, since the facilitator served as activity coordinator and bounced between the two major tasks of the recipe preparation process, fruit tart filling preparation and cutting the fruit, she gained the overall recipe process awareness. This left the other participants with varying degrees of exposure to the overall recipe preparation process. Recall that Candyce had a pretty good understanding of the overall recipe preparation process because while she was monitoring the pot with the custard filling, she was also looking around and watching Malaysia cut fruit; Malaysia, on the other hand, was intently focused on cutting the fruit with minimal exposure to the preparation process of the custard filling. Thus, without engaging in these social engagement practices, Malaysia lacked a shared knowledge of the recipe preparation process, and this lack of knowledge is what prevented the group from interchangeably taking turns and collectively reflecting on the process, both in writing and orally.

In addition, I found that the participants in Case Study #2 only rarely engaged in information sharing. This seems partly due to participants having not engaged in the other sensory engagement practices of attending to verbal cues from other participants and continuously monitoring others and artifacts. Without these sensory engagement practices, it proved very difficult for the participants to ascertain the value of working together and making collective decisions, processes supported by positioning and activity coordination. Furthermore, with activities that were independent of one another, and only one of those activities able to foster insight into the role starches played in thickening liquids, Malaysia and Candyce worked in relative seclusion from one another, and thus did not have the same experiences as each other.

Lastly, I found that in the absence of these practices in Case Study #2, the facilitator took on the role of making sure everything was done right, an extension of the activity coordination role she'd assumed. However, without the shared understanding and experience of the overall recipe preparation process, gained through participants' positioning and activity coordination, the girls were not able to trouble-shoot what had caused the two fruit tart fillings to come out differently.

6.4 Cognitive Engagement

Up to this point, I have been highlighting and discussing the negative impact that inhibited sensory engagement has on Malaysia's social engagement patterns within small-group activities. In this section, I discuss the negative impact inhibited sensory and social engagement patterns had on Malaysia's cognitive engagement during small-group activities. In this section, I focus primarily on the types of missed opportunities for cognitive engagement that Malaysia experienced from not having the knowledge gained through firsthand and secondhand experiences. In particular, I pay attention to the roles that lack of firsthand and secondhand experiences and lack of knowledge of the changing state of the recipe and preparation process played in inhibiting individual and collective reflection: (1) lack of knowledge about the content/phenomena inhibits the individual from making connections across the big-group and small-group activities; and (2) lack of shared experience inhibits the group's ability to collectively reflect and trouble-shoot unexpected recipe outcomes. As related to KSI participants, these primarily resulted in an inability to fluidly interchange their recounting of the recipe preparation process. It also resulted in the inability of participants to take part in trouble-shooting unexpected results. In addition, I look at the ways that Malaysia was able to overcome gaps in her understanding through her experiences in the big-group discussions and with her conversations with the facilitator during small-group activities.

6.4.1 Missed Opportunities for Reflection-in-Action Created by Lack of Sensory Engagement

As I've already established in previous sections, Malaysia's sensory engagement was inhibited during the small-group activities that seem to further limit her ability to reflect "in the moment". In addition, the extent to which she was able to contribute was limited to what she had heard and remembered from others. Thus, lacking experience with the cooking and scientific phenomena, Malaysia was limited in the extent to which she was able to engage in reflection-in-action.

Episode 6.2 highlights a missed opportunity for Malaysia to reflect-in-action. Episode 6.2 occurs during Session 18, a Choice Day, when Malaysia and Nina are making potato-filled ravioli with Christina, the facilitator. In this episode they were creating the potato filling for the ravioli by testing out different types of potato-based starches to create a mashed-potato consistency. The activity required that the participants taste the two variations of the potato filling.

Episode 6.2 starts off with Nina making a visual observation about the texture of the current sample of the potato filling needing to be more watery. Then Malaysia asks Nina what the sample tastes like. Nina tastes the sample and describes the taste and the texture pointing out that it was lumpy. The facilitator, not knowing that they've already tasted the sample, hands out forks to the girls and tells them that they need to taste it. Malaysia says in response, "We gotta taste what?" and "We just did!" The facilitator then asks them what it tasted like. Malaysia says in response that she is scared to taste it. The facilitator asks what's wrong with it, and Nina says nothing but indicates that it was chewy. In response to Nina's description, Malaysia hollers out, "Stop please. Oh my God, are not you scared? I'm asking." Nina tries to reassure Malaysia that it does not taste nasty. Then Nina and the facilitator use Nina's observations about the filling being chewy and needing to be more watery to make adjustments in the next trial of the sample. Once she's given the reassurance that the filling was not nasty, Malaysia tastes the filling and finds it tastes good. Malaysia continues to taste the filling while Nina and the facilitator devise plans for how they are going to change the amount of the potato-based starch and the amount of water to meet the taste and texture requirements identified by Nina, less chewy and more watery. Malaysia listens to the conversation but does not contribute much except to correct Nina's inaccurate reference to the starch they were using as cornstarch and flour instead of potato flour. However, she does continue to remark about how good the potato filling tastes.

Episode 6.2: Reflecting on the First Batch of the Potato Filling - Session 18 - Learning How to Use Starch Thickeners

Nina: "Yeah, it can be a little bit more watery, but not as watery as I stirred it up some more..."
C: "So maybe we should add a little less starch."
(0: 39: 25.9) Malaysia: "What it taste like?"
Nina: [Nina tastes the filling] "It kind of tastes like mashed potatoes that's lumpy."
C: [returning with forks in her hands] "Alright, you gotta taste it." [Handing them forks]
Malaysia: "We gotta taste what?"
C: "That!"
Malaysia: "We just did!"
C: "Oh, how did you like it?"
Malaysia: "I'm scared."
C: "What's wrong with it?"
Nina: "Nothing [holding fork in her hand], it's just a little..."
C: "A little chewy. We gotta make it less chewy."
Malaysia: "Stop please. Oh my God, aren't you scared? I'm asking."
Nina: "It's not that nasty, I'm just…" [Puts fork in her mouth]
C: [walks back over] "Alright, maybe…"
C: "Okay, so we're gonna try it again. We're gonna try it again - one time because we'll have to figure out if the chicken broth is making it kind of chewy. So we'll try it with water."
Nina: " No, if it's too much, because you know how it soaks in liquid, then it was like a lot of um…"
Malaysia: [Malaysia tastes the filling.] "Oooh, this stuff kind of good."
C: "So what do you think you should do?"
Nina: "I think we should put less, um, flour or cornstarch in there."
C: "Oh less - well we're not using cornstarch, what are we using?"
Nina: "Flour."
C: "What is it called? But it's not just flour…"
Malaysia: [putting some more in her mouth] "Potato flour."
C: "Potato flour, OK, OK. So how much do you suggest we use?"
Nina: "We used a half of a cup?"
C: "We used a fourth of a cup."
Nina: "I think we should use half."
(0: 41: 03.3) C: "Half, goes up, half makes it more."
Malaysia: "Ooooh, this is good!"

Since Malaysia was not initially comfortable tasting the fillings, she had to rely on Nina and the facilitator's assessments of the textures and tastes of the fillings.

Furthermore, Malaysia was unable to participate in the conversation about which type of starch to pick, and how to adjust the amount to get it to the right texture, due to her refusal to sample the fillings. This limited her ability to contribute her opinions about the texture in the discussion her group had about how they should tweak the preparation process to reduce the chewiness. In addition, this ability was further hampered because once she overrode her aversion to tasting the filling, she spent the duration of the filling-tweaking conversation tasting the filling. During this particular session, Malaysia flipped back and forth between being engaged and not engaged. Evidence of her disengagement was seen in the frequent breaks she took to sit at the table with her back to the stove while the facilitator and Nina worked to get the potato filling to the right texture.

Episode 6.15, on the other hand, highlights the ease with which Malaysia contributes to discussions based on her opinions of food artifacts. Episode 6.15 occurs during Session 15, Malaysia's first day in KSI. Notice that despite not being involved in the preparation of these artifacts, Malaysia easily shared her opinion about which pie filling artifacts were more spread-able multiple times in this episode.

During Session 15, the participants were having a big group discussion about the texture and consistencies of the strawberry pies. The facilitator, Tammy, was trying to help the participants draw out rules of thumb about the number of tablespoons needed to create a strawberry filling of a specific texture. In this episode, the facilitator is specifically trying to help the girls think about when they can use each of the consistencies in preparing new recipes. The focus of the conversation is on which of the fillings would be useful as a filling for making sandwich cookies from Amber's, one of the participants, sugar cookies.

Episode 6.15 starts off with the facilitator asking the participants which spread they would use to fill the sugar cookies. Malaysia points to the strawberry pie labeled "D." Then when prompted to explain why by the facilitator, Malaysia responds by suggesting that it is spreadable and describes spreadable as "glumpy," thick, and spread out. The facilitator, TLC, then uses Malaysia's definition of spreadable as she spreads out Malaysia's strawberry-pie filling selection on the paper mat. She then playfully interacts with the facilitators as she describes her selection as being better than the others and suggests that the graham cracker crust of the pie and the filling are in a relationship.

Episode 6.15: – Session 15 - Learning How to Use Starch Thickeners
Context in which spreadable is introduced
46: 40
TLC: "Think about, think about Amber's wonderful sugar cookies right, and if we were gonna kick those up just a little notch and we wanted to make those sandwich cookies, which, which one would we want to put? **So we see the different spreads, which spread would you want in between the cookies?"**
Malaysia: "This one [pointing at D]!"
TLC: "Why?"
Malaysia: "Cause it looks, spreadable." [Someone laughs]
Someone: "Spreadable."
TLC: "Cause it looks - so why does it look spreadable?"
Malaysia: "Cause it's all thick and the rest of them are all spreaded out and…"
Someone: "Glumpy."
Malaysia: "Glumped and thick, and all spread out"

JLK: "I don't know, I didn't think this one looks a whole lot different."
Malaysia: "I like mine better." [Laughs]

TLC: "Well one thing that you said is that it spreaded out. So we see blank spots, so we see kind of the way that those were spreading, and here we see yours kind of really sticking."
Malaysia: "Together."
TLC: "Really sticking together."
JLK: "Well they've got some pieces of the graham in..."
TLC: "Ohhh, OK."
Malaysia: "They in a relationship."
TLC: "Yeah."

Malaysia: “These things.”
[Talking and playing, *Malaysia goes off on a tangent in thinking that since one of the jellies or preserves is sticking to something that it is now in a relationship.]*

This episode shows Malaysia’s ability to reflect on which of the strawberry fillings were spreadable and most appropriate for making sandwich cookies came from watching others spread the pie fillings earlier. Earlier in the session, Malaysia did not know what spreadable and was quite averse to using the knife to spread the spread (Episode 6.1). (Note: this was very similar to Malaysia’s initial resistance to taste the potato filling for the ravioli). However, after she because more comfortable watching others as they tasted and manipulated the strawberry pie fillings, she began interacting with the fillings herself. Thus through her own interactions and others in the big group discussion, she began forming her own opinion about the textures of the pies.

So these three episodes raise two questions: Under what circumstances was Malaysia able to engage in reflection-in-action? Was there a difference between the small-group activities and the big-group activities in promoting Malaysia’s reflection-in-action? In general, when discussions of food focused on opinions of the final food artifacts and did not require her to taste and touch artifacts prior to giving her opinion or require her to have knowledge of the food preparation process; Malaysia confidently participated in small-group and big-group conversations.

Evidence to this point is illustrated by my observation of Malaysia’s tendency never to miss opportunities during the big-group discussions and activities to reflect-in-action. Episode 6.15 highlights Malaysia’s ability to reflect-in-action when she was watching others as they interacted with artifacts and looking at artifacts that were easy to see and inspect from a distance during the big-group discussion. The big-group activities seemed to foster her awareness of what was important to focus on because she was able to see others' manipulating artifacts or had the opportunity to manipulate the artifacts herself once she became comfortable.

On the other hand, the small-group activities that required Malaysia to reflect-in-action seemed to be more fast-paced and not give her time to warm up to tasting or touching food artifacts, so she voluntarily disengaged. This voluntary disengagement was only compounded by the involuntarily isolation from continuous monitoring of others and artifacts because of where she was positioned in the workspace. This isolation resulted in missed verbal cues that could have focused her attention on opportunities that highlighted phenomena of significance or important conversations.

6.4.2 Missed Opportunities for Reflection-on-Action Created by Lack of Social Engagement

To facilitate participant reflection-on-action during KSI small-group activities, we prepared reflection questions in advance to prompt them to notice particular features of the artifacts they created in addition to providing them free form places to reflect. However, as previously discussed, Malaysia's group did not engage in sensory and social engagement patterns that promoted their participation and cognitive engagement in activities. In general, when her group was reflecting on their experiences, Malaysia was disengaged and did not contribute to these discussions even when the facilitator made efforts to pull her back into these discussions. Recall from Episodes 6.9 - 6.12 that she did not want to participate in her group's trouble-shooting process when the fruit-tart filling came out thicker the second time than it did the first time they made it. This was possibly due to the fact that she did not have any firsthand or secondhand experiences to contribute to the discussion. As a result, not only did she miss seeing it happen the first time, she also missed the opportunity to listen in on the conversation about what possibly caused the difference.

In addition, when Malaysia was encouraged to write a story by the facilitator, it was on the condition that the facilitator would write it because she Malaysia did not want to type her own story since it was too much like school (Episode 7.20). Thus, Malaysia had no problem telling the facilitator what she wanted written for her story or explanatoids. However, recall that in Episode 6.14, that Malaysia was limited in the extent to which she was able to reflect on her experiences, as evidenced by her discussion of the story focusing on what her dad thought about the fruit tart when she took the fruit tart to him from the first batch. While Malaysia did not usually contribute to the construction of the stories and explanatoids her group made, she regularly volunteered to report to the other groups what her group had done by reading the explanatoids or story that others created.

These episodes suggest that Malaysia was limited in her ability to reflect on her experiences during the small-group activities. In particular, she was unable to reflect on the preparation process of recipe artifacts and other significant cooking and science phenomena that might have been seen during this process.

However, there were times when Malaysia was able to reflect on her actions. Episode 6.16 highlights Malaysia's ability to reflect her previous experiences when she tasted the foods they created and use those experiences to make decisions about how to move forward in the current activity. Episode 6.16 occurred at the beginning of the small group activity during Session 18, prior to Episode 6.14. At the start of Episode 6.16, the facilitator, CMG, describes the goal of the activity as being aimed at creating a mashed-potato consistency from potato-based starches and making a cream sauce that is smooth and thin/thick enough to coat the pasta. To help the girls make recommendations about the amount of starch they should use initially to make the potato filling for the ravioli, the facilitator asks the girls to think back to the previous sessions when they made the filling for the fruit tart (Malaysia) and the nacho cheese sauce (Nina). Malaysia recalls the nacho cheese filling and suggests that it was congealed and stretchy and that her fruit-tart filling was creamy. Then she recalls that her second batch of fruit-tart filling came out messed up.

Episode 6.16: Session 18 - Learning How to Use Starch Thickeners
CMG: "OK, so our recipe calls for bringing a pot of water to a boil, and then putting in - [reading laptop] basically, we boil the, um, the potatoes. And basically, we need the potatoes to be a mashed potato consistency. OK?"
Malaysia: "We gone turn that [referring to the potato starch and potato flour] into mashed potato?"
CMG: "Yeah, so we gotta figure out how to get it thick enough to be a mashed-"
Nina: "Mashed potato?"
CMG: [nods] "Consistency."
[Discussion about making the pasta dough, which we don't do during this session because we use wonton wrappers]
CMG: "OK, and then the other part is we gotta make the cream sauce, so we gotta have the cream sauce nice and smooth, but thin enough."
Malaysia: "That's the cream sauce [points at something on table]?"
CMG: "- thin enough, to um, to stick to the, um, ravioli, but not too thick. So we gotta figure out, so we got two different textures we're trying to get, okay? So, how much, you know how when you - were you guys both here when we made um, pudding?"
Malaysia: "Fruit tarts?"
CMG: "Uh - oh, well you made the fruit tart pudding, you made-" [pointing at Nina]

Nina: "Nachos."
CMG: "You made the nachos. OK, so we'll, we'll think about those things. How thick should we want the sauce to be? Do we want the sauce to be as thick as the nachos?"
Malaysia: "That's..." [Inaudible]
CMG: "And, the cream sauce, or do we want the filling to be as thick as the pie filling? How, like [hand motions], so is that kind of, we have to kind of think about thickness that way."
Malaysia: "But like the cheese was like, congealed, like [hand motioning], like it was all like when we stretched it [stretch motions with her hands] [Nina and Malaysia laugh], it was all stretchy. But our pie crust was like, you could move it around, it wasn't all [?]Stuck up, it was like creamy."
Nina: "Was it thin or [hand motions] or thick [places hands further apart]? [Malaysia doesn't say anything] Thick?"
CMG: "What the cream sauce?"
(0: 16: 50.2) Nina: "Our nachos cream, was like [places hands close together] wouldn't move."
CMG: "It was thin but then it got thick, remember? So we might need to use a little less, so we'll have to play around with that to make it not too thick. So,…"
(0: 16: 59.8) Malaysia: "But our second batch was like messed up because we had to" [she continues but it is inaudible]

In this episode, Malaysia was able to reflect on her previous experiences to contribute to the discussion of what consistency they should get their potato filling. In this discussion, Malaysia was able to contribute her experiences having tasted and interacted with Nina's nacho cheese dip and the fruit tart filling Malaysia's group had created during the two previous sessions. Based on these experiences, she was able to be very descriptive about the way that she wants the cream sauce to come out to be an active participant in the conversation about the texture they should aim for their potato filling to have.

The key thing to note about the social engagement pattern represented in this episode lies in the interactions the facilitator has with Malaysia. In particular, the facilitator specifically prompted her to reflect on the previous foods she'd tasted and for which she desired to taste. This stands in contrast to prompts by the facilitator to taste new foods in which she was scared to taste and thus able to reflect in the moment or later on those interactions.

The episodes presented in this section suggest that the social engagement pattern that fostered reflection-on action for Malaysia was due to direct facilitator engagement during the small-group activities. In particular, Malaysia was happy and willing to reflect on her previous experiences as long as she did not have to write about them herself, but even then, she struggled to talk about more than how the recipe came out and who liked it. In addition, Malaysia was happy and willing to reflect on her previous experiences when they were being used in planning and specification of the texture of a dish. Since she did not have a lot of experience preparing the part of the recipe where she saw the mixture thicken, she was not able to contribute much about what to expect from using the different types and amounts of starch thickeners.

6.4.3 Missed Opportunities to engage in Reflection Designed into KSI created by Inhibited Sensory and Social Engagement Patterns

Since many of the sensory and social engagement practices that were designed to promote cognitive engagement did not manifest themselves in Malaysia's small-group interactions, Malaysia also missed opportunities to reflect during activities designed to promote reflection. KSI was designed to foster firsthand and secondhand opportunities for participants to experience scientific phenomena in with which they could later reflect on and make connections to science explanations and demonstrations provided during the big-group discussions. We imagined that reflection would happen naturally as participants' prepared to share and shared their variation results and cooking experiences in the big-group discussions. However, for Malaysia the scope of her reflection on the small-group activities was limited because of her inhibited sensory and social experiences.

Episode 6.17 took place during Session 17 during the ending-group discussion, and highlights Malaysia's scope of reflection. Notice that she was only able to reflect via the reading of the stories they'd created in the group, although her contributions to the writing process were modest (recall Episode 6:15).

Episode 6.17: Session 17
Candyce walking around to back table and glancing at something on the back table
TLC asks which group wants to go first, Candyce immediately raises hand: "Us!"
Candyce's group: SWV Cuties
JLK: "We're..." [Talks about cutting their pie in half, waiting to see how well it cuts and points to the knife they were using]
JLK: "We have a bunch of stories." [Calls Malaysia and Candyce to come up and talk]
Candyce remains seated, looks over to where Malaysia and JLK are
JLK: "Start out by talking about why we used arrowroot and white rice four." [Holding a sheet of paper in her hand off camera]
JLK: "Alright, we, we are ready. Malaysia, come up front..." [Laughs]
CMG: "You get up there too [to Candyce]
[Candyce stands up and goes to front, JLK shows the fruit tart to everyone Malaysia holds papers in her hand]
Malaysia: [Talks about how they switched the ingredients around and why]
JLK: "Tell them why we used arrowroot and white rice flour"
Candyce: "We looked at where we made the pudding."
Malaysia: "In the advice column."
Candyce: "Yeah, in the advice column, and we looked at the pudding recipes..."
[Candyce talks about the charts they looked at from when puddings were made and how they decided arrowroot and white rice flours based on what their goals were]
Malaysia: [looks at paper to talk about results and refers back to what people said about their puddings]
TLC: "Why didn't you get the fruity smell?"

[Candyce and Malaysia talk about why not
Malaysia uses the word congealed when Amberstarts talking.]
Malaysia: [says she wants to tell about their rubbery story]
JLK: ”Tell the other one first.”

Candyce: [talks to Malaysia about who reads which story. Candyce’s story talks about when she went home so she wants Malaysia to read her story and she reads Malaysia’s story so that they are talking in the right tense]
JLK: “However! Now where's our previous story?”
Malaysia talks about when they first made it and how it was rubbery
They show a rubbery one that's underneath the fruit
Malaysia talks about how JLK suggested they put it back on heat and add more milk and keep stirring
Candyce interjects: “And that was a great idea, so…”
Malaysia continues: “Every time we stirred it, it got more lumpy and more lumpy, until lumps came out.”
JLK: “What we don't know, is if it is going to stand up when cut into pieces.”
Malaysia: “We don't know if it's going to be ↑congealed.”
JLK: “Congealed, yes...”
Candyce comes to cut pie, Candyce stands in background. She doesn't want to cut, so JLK cuts.
CMG sends JLK over to cut pie
CMG summarizes their recommendation - put it in refrigerator longer or make it a thinner layer

The experiences she was able to reflect upon from her own memory were related to the “thinning-the-filling” process she engaged in after their filling had come out too thick the second time. Thus, she was able to understand that their filling had come out perfectly the first time, and too thick the second time, but she was not able to understand the differences in outcome. Malaysia’s understanding was significantly limited in its reflective scope, when compared to the extent of Candyce’s ability to use her experiences while making the custard filling to reason about the potential causes for the thicker second filling.

However, there were several occasions when Malaysia was able to make connections. These opportunities occurred primarily because the facilitator prompted

Malaysia to get her to make the connections or to participate. Episode 6.18 highlights the social roles that the facilitator played in helping Malaysia engage her senses, and begin to cognitively engage and make connections.

Episode 6.18 highlights an opportunity for sensory and social engagement, created by the facilitator's (CMG's) attempt to encourage Malaysia to participate in the potato filling creation process. Here, she was able to make the connection between the lumps and the starch grains' getting wet. This was fascinating because it was one of the first and only times she made such a connection on her own. I believe it was promoted both by the facilitator's ongoing conversation about the starches and how they worked and by her work with the girls to get them to make observations and to reflect on them in the service of perfecting the potato ravioli filling.

Episode 6.18: **Session 18 - Learning Science Underlying How Starch Thickeners Work**
Malaysia: "Well give me a spoon."
CMG: "Wait, that's gonna be sticky because it's wet." [Malaysia stirs in pot that's not on stove]
Malaysia: "I think that does have something to do with it."
CMG: "What?"
Malaysia: "Mixing it before it gets wet."
CMG: "So that it won't clump, clump together."
Nina: "... stick to the pan." [CMG looks at Nina who's at stove, C standing between stove and table]
Malaysia: "Well how about when you add it, spread it out, so it won't be - like when the water - cause every time you put the water in they stuck, they'll just join together. [Brings hands together] Or like spread it out before you add all that to it."
CMG: "Right, so maybe you can help her add, add it in real slowly. So maybe take like your tablespoon like this [takes tablespoon inside pot Malaysia is stirring at table] and just sprinkle it around. [CMG walks over to Nina] Your butter's melting. You gotta wait for - look up there to see if she has her butter melting so you can help her out with it."
(0: 51: 12.1)Malaysia gets up and goes over to Nina.
Malaysia and Nina play, C tells them they are so silly

C asks them if it looks lumpy, I hear her say good, so it must not be
Nina: “You're going too fast...”
Malaysia: “Shut up.”
CMG turns the heat down, she says it's cooking really fast
CMG: “It's getting brown.”
Malaysia: “...”
CMG: “Yeah, it is getting orange.”
Malaysia: “It's coming back to a regular texture.”

Moreover, the facilitator, CMG, was able to move Malaysia from disengaged to actively engaged. In addition, the facilitator was able to help her to engage cognitively by providing Malaysia with the science content and structure in which she could then make connections between the science and their cooking experiences. Notice that when Malaysia asked for a spoon, and the facilitator said that they were wet, Malaysia instantly made the connection between the wet spoon and the clumping. Furthermore, because she had engaged in the continuous monitoring of the potato filling over several batch iterations, she was able to make a comparison and know that the mixture was returning to its “regular” texture.

Malaysia’s cognitive engagement carried through to the next episode, Episode 6.19, where the facilitator, CMG, was trying to get the participants to notice something and help them make a specific connection. Notice that for the first time, Malaysia was able to use and apply her knowledge about how starches work in the right context. Notice the prompt by the facilitator for the participants to recall what they were learning about how starches work, emboldened in Episode 6.19. Then notice the way Malaysia recalled that starches absorb water. Furthermore, gesticulations accompanied her explanation.

Episode 6.19: Session 18 - Learning Science Underlying How Starch Thickeners Work
CMG: "Come on ladies."
[They go over to the stove.]
CMG: "OK, so, we want - so the way - you guys been learning things about the way starches work?"
Malaysia: "They absorb [holds hand up], like they absorb [?] …"
Nina: "Ooooh, they make little chunky things!"
CMG: "Yeah, they make chunky things, but you were saying they absorb…"
Malaysia: "They absorb water like this." [Hand motions - pulls hands wider apart]
CMG: "They swell."
Malaysia: "Yes."
Nina: "... the, um, liquid."
C: "Right, right so, we started out with one cup of, of broth, right? So what we want to make sure is it's not lumpy, OK ? Right, so, [Malaysia and Nina play], so let's start off I guess with a quarter cup, cause we're gonna, you put, two, you put one cup in there, we'll start off with a quarter cup of each one of our starches."
Nina: [takes cup] "OK."
...

Thus, the one-on-one conversations that Malaysia had with the facilitator, CMG, in this episode were representative of the types of interactions she had with the facilitator in the big-group discussions. While there were a number of opportunities Malaysia missed, because she and her group(s) never engaged in the sensory and social patterns that promoted engagement, her patterns of direct interaction with the facilitator did help her take up some of the affordances of opportunities to make connections between the abstract science and her engagement in activities.

So, how was this type of reflection supported in one small-group situation, but not in another situation in which Malaysia was a participant? Part of the answer is that the activity structures were different. In this episode Malaysia was working with Nina and the facilitator to iteratively improve the potato filling for the ravioli. In the first iteration, the group chose which starch to use in the filling. In the subsequent iterations, they determined what amount to use and what type of liquid (chicken broth or water) they should use as a base to thicken their potato filling in. Thus, Malaysia worked in parallel with Nina, each over a different pot, with a different variation, both having the firsthand experience of seeing the starch thicken the liquid.

Another part of the answer is that the facilitator was constantly engaging Malaysia and Nina in reflection-in-action and reflection-on-action, and providing scientific explanations. By engaging the girls in this level of cognitive engagement, the facilitator modeled her own reflective practice. Malaysia then picked up on the practices modeled by the teacher, and enacted them herself, as evidenced by her explanation of why they should not use the wet spoon to mix in the starch because it would cause lumps.

I observed that Malaysia was stimulated more by conversations than by observations. Thus, we found that Malaysia would come out of long stretches of silent periods by engaging the facilitator and other participants' questions. For example, after one such period of silence, Malaysia asked the facilitator what the KSI research was all about; on another occasion, she asked the facilitator and other participants what they were doing over the weekend, and even asked about their lives. Thus, it was not surprising, when the facilitator engaged Malaysia in conversation, or provided a science-grounded commentary about what they were doing, that Malaysia attended to these verbal cues because those were the types of verbal cues she valued and liked to engage in.

Moreover, those were the types of experiences Malaysia engaged in regularly during the big-group conversations. This social engagement during the big-group discussions included carrying on conversations with the facilitator as if she were the only one in the room, despite the fact that there were 15+ other participants listening in on the discussion. In addition, I found that Malaysia listened intently to other participants as they shared their observations, and when the facilitator was giving explanations or engaging the participants in science demonstrations.

In summary, while Malaysia and her groups were not able to engage in sensory and social patterns that facilitated physical and cognitive engagement during most of the small-group activities, with the help of a more streamlined activity or science explanation, and activity coordination by the facilitator, Malaysia was able to have the firsthand experience of seeing starches thicken liquids and to immediately connect those experiences to the science explanations of how starches thicken liquids. I hypothesize that if Malaysia had been given the opportunity to work in a bigger group and on a recipe that had one central recipe preparation process, she and her group members would have engaged in similar sensory and social experiences. This would have engaged Malaysia's inclination toward dynamic dialogue, as observed in big-group discussions and discussions with facilitators.

6.4.4 Gaps in the Cognitive Engagement Negatively Impact the Resultant Learning

Throughout the last three sections, I highlighted the gaps in Malaysia's cognitive engagement. In this section, I want to highlight the negative impact these gaps had on what she ultimately learned in the KSI Program. I also want to highlight the ways she was able to fill in these gaps.

During Malaysia's first session in the KSI Program, she participated in the big-group discussion in which the group was making observations about the strawberry pie fillings they'd created the week before. During this discussion, her interest in the word “congealed” was sparked. Furthermore, Malaysia’s interest was sustained by her growing understanding of the word; and use of it to describe the textures of starch-thickened foods.

In Episode 6.20, Malaysia returned to her favorite word, “congealed,” to explain the way she wanted the cream sauce for the potato-filled ravioli to turn out. This episode highlighted that Malaysia understood “congealed” to mean “stuck together.” The gap in Malaysia’s understanding of “congealed” at this point was quite pronounced, notwithstanding her participation in two weeks of small-group activities, and various opportunities to see starches thicken liquids, due to the limited number of food textures she’d been exposed to during the program.

Episode 6.20: **Session 18 - Learning Science Underlying How Starch Thickeners Work**
CMG: “We might actually get the sauce before we get the uh filling.”
[Laughs]
(0: 52: 46.4) Malaysia: “Cause we don't want it to be congealed.”
CMG: “So what do you mean by congealed?”
Malaysia: “Stuck together.”

In Episode 6.21, Malaysia expanded upon her understanding of “congealed” to include the texture of “rubbery”, as she described the resulting potato filling of the ravioli to the facilitator, CMG. Moreover, she used the word congealed to describe the desired texture of the cream sauce, as “less congealed”. This suggested that she considered congealed items to be thicker and non-runny.

In Episode 6.21, the group was deciding how to adapt the potato filling to reduce its rubbery texture. Furthermore, since overcoming her fear of tasting the filling, she was now able to use her personal experiences of tasting foods to guide her recommendations as to how they should adjust the recipe in the next iteration. This was important as well, because prior to tasting the filling, she had been unable to make recommendations when the group was deciding how to iterate the recipe.

> Episode 6.21: **Session 18 - Learning Science Underlying How Starch Thickeners Work**
> Malaysia: "I like... [?] It's like all congealed, I mean when it's three [?], not, and I did like that and it was all rubbery."
> CMG: "Oooh, it's rubbery [sounds like she's repeating what Malaysia said.]. So we might, we might make…"
> Malaysia: [with container in hand] "I'm not used to rubbery potatoes."
> CMG: [tastes] "It's really not that rubbery. What?"
> Nina: "It looks like our first one."
> CMG: "Yeah, but without the lumps. There's no lumps in this one. I didn't add all the water, I only added, um, like a half a cup of water.'

During Malaysia's first two weeks in the program, big-group discussions taught her that starches absorb and swell. Prior to making the potato filling for the ravioli, she'd lacked concrete firsthand and secondhand experiences with the thickening process. At this point, Malaysia finally took up the affordances of an opportunity to fill in the gap in her understanding of how starches thicken liquids, in the form of the potato starch thickening the chicken broth they were using as a base for the potato filling. This understanding was critically important, for without it, she merely had "head" knowledge of the thickening process of starches. Thus, this gap was between what she was able to learn from hands-on experiences, and what she saw on her own. Over time, her gap in firsthand experiences of seeing starches absorb water was bridged, but Malaysia was handicapped for a while by it.

After Malaysia's opportunity to see the potato starch thicken the chicken broth for the potato ravioli filling in Week 18, she had another opportunity to see starches absorb water and expand. This opportunity came later in the session, when the girls used wonton wrappers as pasta sheets, filled them with the potato filling they'd created, and put them in boiling water to cook. During this experience, she was able to see the wonton wrappers expanding in the water. She had this experience again, during Session 19, when they made their own homemade pasta sheets. Since the pasta was so fresh, the pasta sheets greatly increased in size when boiled, so much that Malaysia was able to quantitatively estimate their increase in size, by utilizing the ratio of the area the meat filling occupied to the area of pasta around it. This occurred during Session 20, and is highlighted in Episode 6.22.

In Episode 6.22, notice that when Malaysia was prompted to talk about what had happened to the ravioli when it had boiled, Malaysia was able to explain that the pasta had absorbed the water and expanded. In addition, notice that she messed up a little when she said cornstarch, instead of starch. Part of this word-use mistake had to do with the context in which Malaysia had first learned about starch absorbing water; this had occurred during her first two sessions in the program, when the facilitator was explaining how cornstarch was used to thicken the strawberry pie fillings.

Episode 6.22: **Session 20 - Learning Science Underlying How Starch Thickeners Work**
CMG: "It boiled. And what happened in the inside?"
Malaysia: "It, like, when you boil it, like at first, when we boiled it, it was like big, but it was medium-sized, and the meat, we put enough, because, we put enough in there that it would fill it up. But when we boiled it, it got bigger, so the meat was like small. It was like a little meat. So,..."
CMG: "And how did the pasta, what happened, how did the pasta do that?"
Malaysia: "It absorbed - the cornstarch absorbed the…"
CMG: "The flour."
Malaysia: "Yeah, the flour had absorbed the water and expanded."

Candyce: [?]
Malaysia: “Yeah. [Turns to Candyce and points] congealed.” [Candyce laughs]
T: “That's her new word.”

Notice in this episode that Malaysia enthusiastically shared her knowledge with the parents during the parent presentation during Session 20 that flour/starch in the pasta absorbed water and expanded because of the meat to pasta ratio, before and after it was cooked. These opportunities to fill in the gaps in her understanding were provided by the one-on-one interactions between Malaysia and the facilitator. During these experiences, the facilitator was able to help Malaysia focus her attention on the phenomena.

In addition, the significance of this episode was in showing that Malaysia was able to reflect on the science when specifically prompted to do so. Thus, she had learned it, but she still needed the facilitator to prompt her, since it was not within her own ZPD to share that type of information. Furthermore, notice that Malaysia was coming full circle in that the initial word that sparked her cognitive engagement, congealed, was now being associated with flour absorbing water and expanding.

However, since Malaysia was highly focused on preparing something she could take home and share with her family and showing off her cooking skills and knowledge, she often focused on sharing the preparation process, rather than the science. Thus, she did not automatically provide the scientific explanations for why her food had come out the way that it had. In Episode 6.23, notice that when prompted by the facilitator, TLC, to talk about the ravioli, Malaysia focused on the amount of meat and parsley they’d added to the ravioli filling.

Episode 6.23: **Session 20 - Learning Science Underlying How Starch Thickeners Work**
TLC: "OK, OK, and now what about with the ravioli? I forgot to ask about that. [Malaysia walks towards TLC] Malaysia, did you want to tell us something about the ravioli? And who else was in that group? Candyce, you were there?"
Malaysia: "I made ravioli. Uh, uh Shara."
TLC: "Shara, do you want to tell us anything too?"
Malaysia: "They had Italian sausage in theirs."
TLC: "Oh, OK, so tell us about the differences, tell us about what happened."
Malaysia: [turning to side, facing TLC] "Um, well, in the chicken one…"
TLC: "Tell your parents!"
Malaysia: [turns around, holds paper in her hand] "…and everything, nothing went wrong really, except, [looks at paper], nothing went wrong, we just had to add, we added too much meat, so we had to double the recipe. And then we had added another ingredient, and it was parsley. We added parsley in the uh, in the meat, so it can [pauses, hand motions] so it can taste better! So it can have a better taste, and more, like you could taste it because when it wasn't, when it didn't have parsley, you could barely taste the meat. And then, so, - want me to [?] the Italian sausage?"
Malaysia: "It boiled."

During the last two weeks of the program, when Malaysia was working with the facilitator and other participants around a single table, and was able to listen to what others were saying, she began to remember and make the connections between her experiences and the science. Episode 6.24 was significant because it demonstrated that Malaysia had retained some of the information without being prompted. Notice in this episode that the girls were taking turns reading the explanatoid they created with the facilitator's (CMG's) prompting.

Episode 6.24: **Session 20 - Learning Science Underlying How Starch Thickeners Work**
Malaysia: "We made fettuccini alfredo, and …" [Looks around to group members for more]
CMG: "So we had - they have a series of questions and answers they learned to explain- what's the science behind pasta?"

Malaysia: “Well, the [turns and glances at Shara] [reads] the science behind pasta…” [Points to screen for group]
Shara: “What is pasta made of?”
Malaysia: “Well, pasta is made of flour, water, oil, and salt.”
Shara: “What is flour made of?”
Amber: “Starch granules and gluten.”
Shara: “What are starch granules made of?”
Malaysia: “Amylose and amylopectin.”
Shara: “How does amylose look?”
Amber: “It is a starch molecule and starch that doesn't absorb water [?].” [Glances back quickly]
Shara: “How does amylopectin work?”
Malaysia: “It is a starch molecule and starch that doesn't absorb water. Amylopectin is shaped like a branch and the branch structure traps the water.”
CMG: “So amylopectin does what? Absorbs the water.”
Amber: “Absorbs the water.”
CMG: “It helps the starch granule absorb the water. OK?”
Shara: “What is the white sticky stuff in the pasta pot after you boil pasta?”
Amber: “The white…”
Malaysia: “Residue.”
Amber: “The white residue is, starch; specifically, it is amylose that doesn't absorb the water.”
Shara: “How does the starch get there?”
Malaysia: “The amylose starch - starches in the pasta came out because they don't absorb water.”
Shara: “What happens when you boil the pasta in water?”
Amber: “The pasta expands in the water and it swells up.”
Shara: “Why does the pasta expand?”
Malaysia: “The amylopectin starch molecules, they absorb water and swell.”
Shara: “What happens when you over-boil pasta?”
Amber: “It will stick and clump up and get all gooey.”
Shara: “What happens to the starch granules? - Why is pasta chewy and stretchy?”
Malaysia: “The gluten is a protein that makes the pasta chewy and stretchy.”
CMG: “Where does the gluten come from again?”
Malaysia: “The f – oh…”
Amber: “Go ahead.”
CMG: “Where does it come from?” [Malaysia waves for Amber to talk.]
Amber: “It comes from the um, pasta, like the…”
Malaysia: [whispers] “Flour.”
Amber: “Like the starch granules.”
CMG: “And what are the starch granules in?”

Malaysia: "Amylose."
Amber: "lose"
Malaysia: "Amu…"
CMG: "In the flour!"
Malaysia: "Yeah, flour. I was gonna say that."
Shara: "Why is pasta sticky?"
Amber: "The starch makes it sticky."
Shara: "How long should you cook homemade pasta?"
Malaysia: "Four minutes." [Malaysia begins clapping]

Notice that there were several occasions when Malaysia stopped reading the explanatoid and interjected her own answers to the questions recorded in the explanatoid (I've highlighted these in bold). In a funny reversal of roles, Malaysia was able to correct Amber on how to pronounce "amylose". Recall that Amber had introduced the word "congealed" to Malaysia, which she was unable to pronounce for a while, invariably leading to Amber's constant corrections. Moreover, at this point, the facilitator was asking the participants questions not recorded in the explanatoids, and Malaysia was able to successfully draw on her memory to answer the questions. She was also able to provide assistance to other participants by whispering the answers.

Furthermore, this episode was interesting, because it highlighted the extent to which Malaysia cognitively engaged at the end of 6 weeks and evidence that she did learn despite the limitations on the depth and breadth of experiences she gained through her participation in small-group activities. Up to this point, she tended to focus on the recipe preparation process she had personally overseen, and when prompted with scientific questions she offered single-word or short-sentence responses. This episode however, shows Malaysia offering her own scientific responses without promoting.

In Episode 6.16, recall that Malaysia was able to make connections between the big-group discussions and the small-group discussions when prompted. In this episode, Malaysia was able to connect the outcome of their fruit tart filling (with the type of consistency she was looking for), with the consistency she was aiming for with the potato filling for the ravioli.

In summary, Malaysia learned a lot through the big-group discussions about how starches absorb water and expand when heated, though she'd initially had gaps in this understanding because of her lack of firsthand and secondhand experiences seeing the phenomena herself. These gaps were overcome primarily through one-on-one interactions with the facilitator's encouragement to pay attention to the starches thickening liquids, and through providing scientific explanations about the changes they were seeing while they were making the potato-based ravioli filling and boiling the ravioli. In addition, the activity structure provided ample opportunities for Malaysia to revisit experiences she'd initially missed, due to both her late entry into the program, and her frequent work on other parts of the recipe preparation process that did not give her experience with the starches, and the process by which they absorb water and expand.

In particular, the activity structure offered multiple opportunities for participants to gain the firsthand experience of seeing the starches thicken, through the following: (1) the Pudding Experiment with different starches; (2) the Strawberry Pie Filling Experiment with different amounts of starch; and (3) four sessions of Choice Day activities. Malaysia had missed the first two opportunities to see starches thicken liquids since she was not in the program for the Pudding and Strawberry Pie Filling experiments. However, she eventually did have the opportunity to reflect on the Pudding Experiment results provided by the KSI Experiment Software tool. In her first two sessions in the program, she was able to see firsthand the results of the Strawberry Pie Filling Experiment. However, through these experiences, she still had not gained firsthand experiences with and knowledge of the process. Moreover, she also missed opportunities to see starches thicken liquids on the first two Choice Days, when her group was making the fruit tart with custard filling. It was not until her third session in the program that she had her first experience seeing starches thicken liquids, when she made the potato filling for the ravioli. During that same session, she had the opportunity to see the wonton wrappers/pasta sheets expand in water when they boiled their potato-filled ravioli. Then, during subsequent sessions, she was able to see the expanding pasta phenomenon several more times.

Thus, Malaysia was able to overcome the gaps in her understanding and experiences through the diversity of experiences provided by repetitive activity structures, and the one-on-one conversations she had with the facilitator.

6.4.5 Overall Cognitive Engagement Summary

In this section, I've focused primarily on the types of missed opportunities for cognitive engagement created by Malaysia's lack of experiential knowledge, gained through firsthand and secondhand experiences. In particular, I've paid attention to the role that the lack of firsthand and secondhand understanding and knowledge of the changing state of the recipe and preparation process played in making individual and collective reflection work. Malaysia's inhibited sensory and social engagement patterns resulted in a: (1) lack of knowledge about the content/phenomena inhibited the individual from making connections across the big-group and small-group activities; and (2) lack of shared experience inhibited the group's ability to collectively reflect and trouble-shoot unexpected recipe outcomes. This primarily resulted in an inability to fluidly interchange their experiences preparing the recipe, which finally ended with the reading of each other's stories. It also resulted in the inability of participants to take part in the trouble-shooting of unexpected outcomes together.

While the participants featured in both case studies focused on the recipe preparation process, the participants in Case Study #2 were unable to reflect on the scientific content of their experiences. These participants tended to focus on the recipe preparation process they'd personally overseen, and were only able to give scientific answers when prompted;

Thus, the key to Malaysia's cognitive engagement was facilitator-prompted reflection. She learned science content, but it was mostly focused on what she learned in big-group discussions. And Malaysia still needed the facilitator to prompt her to reflect on the science because it was not within her own ZPD to share that type of information by herself. Facilitator's prompting and conversational engagement ended up being the central way Malaysia learned, in both the big-group and small-group activities. In addition, Malaysia learned a lot in the last three weeks of the program while she worked in parallel with and alongside other participants who were doing the same tasks. It was during these times when Malaysia was working with the facilitator and other participants around a single table and was able to listen to what others were saying, that she began to make connections between her experiences and the underlying science. Prior to this, Malaysia's cognitive engagement was characterized by remembering connections others had made or told her.

In summary, while there were a number of opportunities Malaysia missed because she and her group(s) did not engage in the sensory and social patterns that promoted cognitive engagement, her patterns of direct interaction with the facilitator did help her to take up affordances of opportunities to make connections between the abstract science and the activities.

In particular, Malaysia's group did not engage in the practice of continuously monitoring each other, nor did they engage in the practice of checking over one another. She did not want to participate in the group trouble-shooting process because she did not have any firsthand or secondhand experiences to contribute to the discussion. Thus, she missed opportunities to listen in on the conversation and to offer suggestions the other participants might not have thought of. Malaysia did not want to type her own story or explanatoids, though she had no problem telling the facilitator what she wanted written for her story or explanatoids. She also regularly volunteered to report to the other groups what her group had done, by reading the explanatoids or story VW had made with the facilitator's help, despite Malaysia's listening or contributing to the discussion. This was characteristic of Malaysia's cognitive engagement: it directly resulted from interactions with the facilitator, rather than with artifacts, phenomena, or peers. Thus, her discomfort with tasting foods also inhibited her from having firsthand experiences used for purposes of reflection.

However, Malaysia was really good at offering her opinions and describing her experiences when prompted. She seemed capable of reflection-in-action when an activity did not require active participation but required only her impressions about the activity. The times when she shared her thoughts were often times when the outcome allowed her to be confident and to demonstrate competence. In particular, I noticed that she did not miss opportunities to reflect-in-action in the big-group discussions and activities.

Furthermore, because of the gaps in her experiences, Malaysia often focused on the firsthand experiences that she had in the small groups: planning which starch to use, cutting fruit, and thinning out the too-thick fruit tart custard filling. Thus, the scope of her reflections was limited to her firsthand experiences; she occasionally reflected on the results of her activities since she had experiences with these as well. But, as I mentioned in Section 6.4.1, Malaysia was not able to engage in the sort of reflective conversations that required knowledge of the preparation process until she was able to have firsthand experiences with which she could reason, and connect them with the science of how starches work.

6.5 Overall Case Study #2 Summary

As I mentioned at the beginning of this chapter, getting participants to engage cognitively can be difficult in learning-by-doing activities. This chapter offered insight into the ways that sensory, social, and cognitive engagement inhibited learning learning-by-doing learning environments. In this case study, I told the story of how Malaysia's sensory and social engagement in the KSI activities inhibited her cognitive engagement, which subsequently limited what she was able to learn in the KSI Program. In particular, I used this case study to gain a better understanding of what inhibited an inquisitive and reflective participant from engaging in and learning from learning-by-doing activities in ways we would expect her to.

In addition, at the beginning of this chapter I raised several questions I now want to answer.

1. What impact did Malaysia's missing the initial firsthand experiences have on her later learning?

Malaysia missed the firsthand and secondhand observations of the pudding getting thick because she came into the program after this activity was completed. She also missed opportunities to work with others in groups and was unaware that the cooking the girls were doing was resulting in phenomena that could be interesting. This initially left Malaysia with a gap in her understanding: between the science explanations and the demonstrations of starches thickening; of artifacts of starch-thickened recipe results; and of firsthand experiences seeing the starches thicken the liquids. And it left a gap in her awareness of how to participate. She eventually gained firsthand experiences seeing starches thicken, when she made the potato-based ravioli filling, and when she cooked the ravioli and saw the pasta increase in size. Thus, her missing of initial firsthand experiences was overcome by repeated opportunities to experience the phenomena in different activities. In addition, the facilitator played a huge role in helping her fill this gap, by engaging Malaysia in one-on-one conversations that directed her attention to phenomena, and through providing just-in-time explanations. These one-on-one conversations seemed to increase Malaysia's awareness of how to participate; they helped her contribute and find a place to participate without penalizing her for having missed so many of the earlier activities. In addition, her awareness of how to participate was increased through observation of other participants during the big-group discussions; after she observed them sharing their observations and asking questions, she began to do the same.

2. Given that participants' recipe-preparation goals during small-group activities were the same across enactments, what kept Malaysia from participating in ways conducive to learning during the small-group activities?

The recipes prepared during Choice Days in Enactment #2 were easily split up into several parts. This allowed participants to take on distinct roles without requiring them to jockey for a turn. Without the turn jockeying, Malaysia and her group members did not have to observe what others were doing. The lack of interdependence between resources created less contention for material resources, which further negated the need for participants to use positioning and activity coordination to have a turn in the preparation process. This simple shift in the complexity of activities and the removal of material contention removed the need for Malaysia and her group members to intentionally continuously monitor each other and the artifacts they were each preparing.

With respect to positioning and activity coordination, Malaysia either was not able, or did not desire, to position herself, hence the facilitator positioned her. However, by the end of the program, she might have been ready to take on these roles. I believe this to be so because Malaysia had a way of always dropping back to take in all the activities and interactions of the other participants and the facilitators so she could understand what was going on. I saw Malaysia engage in all KSI activities in the same way that had allowed her to overcome her initial aversion to tasting food, accomplished by observing others and seeing that it was not a horrible activity. Confident and competent engagement and performance were keys to Malaysia's development.

I thus believe that at the beginning of her KSI experience, she recognized she was coming in at the middle and that she'd missed a lot, so she hung back to catch up, and catch up she did. I also think her struggles in her science class might have also made her stand back because she did not want to relive that experience in KSI. But once she realized she could be herself, and that being herself helped her engage and learn, we saw her asking more questions, exploring foods, providing her own explanations for her experiences, and taking the initiative to learn more and explain to others what she learned. This is why I believe she would be able to take on, and come to desire to take on, greater responsibility in small-group activities and to engage in positioning and coordinating activities with the other participants.

In summary, I've identified the following factors as inhibiting Malaysia's sensory, social, and subsequent cognitive engagement and learning:

1. Sensory Engagement
    a. Tactile engagement was inhibited by her aversions to tasting and touching foods. This limited the scope of her firsthand experiences, which subsequently limited her ability to reflect on the tastes and textures of food. Thus, she was unable to form her own opinions and had to rely on others' opinions, and she was limited in her ability to participate in reflection and planning activities.
    b. Visual engagement was inhibited because the Choice Day activities had multiple parallel parts that allowed Malaysia to work independently of other participants. Thus, materials were not interdependent, and continuous monitoring of artifacts and others was not necessary. Without this continuous monitoring, Malaysia missed opportunities to see focal phenomena and

changes in the phenomena. Thus, she had to rely on the conclusions of others and visible results of the other recipe preparation process since she lacked both the firsthand and secondhand experiences with that process. Malaysia's primary activities centered on engagement in aspects of the recipe preparation process that did not afford her the opportunity to see the changing phenomena of interest.

c. Verbal/auditory engagement was inhibited because she did not make any visual indications or acknowledgements of verbal cues that signaled other participants' interest, occurrence, changes of focal phenomena, and unexpected results. Furthermore, she acknowledged and dismissed verbal cues that signaled school-related subjects, concepts, or tasks (e.g., science, ratio, and writing).

2. Social Engagement

   a. Participants' positioning and activity coordination were inhibited because the facilitator took on the role of reading the recipe, positioning participants, and otherwise coordinating the activity. Moreover, the parallel recipe preparation processes with independent ingredients did not require participants to coordinate their efforts. Thus, those two factors inhibited the participants from engaging in practices of actively listening for verbal cues of others reading the recipe, or reading the recipe themselves, to acquire essential ingredients. Finally, participant positioning and activity coordination through recipe-reading were inhibited because Malaysia's group did not engage in the sensory engagement patterns of attending to verbal cues, and constant monitoring of activities and others, that were foundational to practices of the boys in Case Study #1. Without the attention to verbal cues, continuous monitoring, and positioning, which created interchangeable participation patterns to complete the preparation of the recipe, Malaysia and Candyce were not able to collectively reflect and build upon one another's experiences because they did not have enough shared experiences. I found that activity coordination for this group became a matter of splitting up the tasks and switching who was doing the task, without continuous monitoring. Furthermore, activity coordination for this group was best characterized by a "split and switch" method, where each participant assumed a role and did it to completion by oneself. If another person picked up the role, the others did not watch. Thus, the primary inhibitor was the independence of the activities, and the group size was so small that there was no contention for tasks to perform.

b. Sharing with others and collaborative decision-making were inhibited because participants did not engage in the positioning and activity coordination patterns that were seen in Case Study #1. It seemed that in the absence of continuous monitoring and interdependence of activities and materials, Malaysia and Candyce did not always value conversations about what had happened to the artifacts. Furthermore, decisions were often made between the facilitator and one participant, since other participants were not always interested in contributing to the decision-making process. This created a discontinuity between what participants planned to do and what was actually done. Furthermore, it limited the opportunities for participants to make significant connections between the plan and what it actually took to implement the plan. Furthermore, it limited them from seeing if the plan worked or did not work, and why. In particular, Malaysia was unable to see the phases the milk and starch went through to thicken.

c. Catching and correcting mistakes, and making sure the activities were done correctly, were inhibited because Malaysia did not engage in continuous monitoring patterns, and as a result she did not have a general awareness of what activities in the recipe were being conducted, nor knowledge of the tools available, nor other important details that supported participants in identifying potential mistakes before they became irreversible. Moreover, since Malaysia did not have knowledge of the recipe, aside from what she was told to do, she did not have the knowledge to know if something was done correctly or incorrectly, even if she had been watching.

3. Cognitive Engagement

   a. Missed opportunities for reflection-in-action were caused by Malaysia's lack of sensory engagement, which limited her ability to reflect in the moment. This resulted in very little reflection-in-action on artifacts, few spontaneous conversations, and an un-stimulated desire to share verbal and written observations with group members.

   b. Missed opportunities for reflection-on-action were caused by Malaysia's lack of social engagement because her group did not engage in the practice of continuously monitoring each other, or the practice of checking over others' activities to ensure they'd been done correctly. In addition, Malaysia did not want to type her own story or explanatoids (Episode 6.14), nor did she want to participate in her group's trouble-shooting process because she did not have any firsthand or secondhand experiences to contribute to the discussion (Episodes 6.9 - 6.12). As a result, she missed the opportunity to listen in on the conversation, and to offer suggestions other participants might not have thought of.

c. Furthermore, she missed opportunities to reflect because she made only sporadic observations throughout the recipe preparation process, and did not have a continuous experience throughout the activity as a whole. Thus, there was a gap between the planning she did in selecting the starches for the filling, and the results she saw at the end. This gap was due to the fact that Malaysia had missed the opportunities that would have allowed her to see the process by which the starches thicken the liquid. Thus, by not having the firsthand experiences of seeing the starches thicken in the initial experiments, coupled with the lack of firsthand experiences of seeing the starches she chose thicken the milk in this activity, Malaysia was not able to make a connection between how her plan thickened the resulting filling. This sporadic observation was caused by her intense focus on fruit cutting. It seems that activities that require participants to spend a long amount of time not engaged in the phenomena of interest can inhibit their individual cognitive engagement, and their observation of other participants' cognitive engagement. In this case, the connections a participant is able to make about how starches thicken liquids are governed by the connections others make for her. In Malaysia's case, she repeated when asked.

So, these findings raise several questions: Under what circumstances was Malaysia able to reflect-in-action? Malaysia was able to reflect-in-action when she was participating in big-group discussions, and watching others do things, and looking at artifacts that were easy to see and inspect. So what were the differences between the small-group activities and the big-group activities? The big-group activities seemed to foster group awareness of what was important, by having all of the discussion grounded in physically present artifacts, and being able to see people manipulating them, or getting an opportunity to manipulate the artifacts themselves. The small-group activities that Malaysia participated in isolated her from seeing and watching what others were doing. Furthermore, she missed verbal cues used to focus in on opportunities where items of significance were available for observation. In the next chapter, I use these questions about circumstances and conditions for reflection-in-action and engagement to identify additional factors that may affect participation and learning in learning-by-doing learning environments.

CHAPTER 7

CROSS-CASE ANALYSIS: PHYSICAL, MATERIAL, AND SOCIAL CONFIGURATIONS THAT PROMOTED AND INHIBITED LEARNING AND ENGAGEMENT

7.1 Introduction

In Chapters 5 and 6, I highlighted the factors that promoted and inhibited learning. Case Study #1 highlighted the roles that sensory and social engagement played in fostering cognitive engagement. Case Study #2 highlighted the effects inhibited sensory and social engagement had on participants' cognitive engagement. One might be tempted to conclude, based on the case studies, that participants' personal preferences, idiosyncrasies, and personalities were primarily responsible for their ways of participating. Perhaps the boys in Case Study #1 participated so enthusiastically because they loved cooking or wanted to outdo each other, and perhaps Malaysia participated less enthusiastically because she preferred cutting fruit to stirring unappetizing (to her) mixtures. That would not be an entirely erroneous conclusion. However, comparing Malaysia's participation during small-group activities to her participation during big-group activities suggests it would be an incomplete conclusion. During big-group activities, in direct opposition to her participation in small groups, Malaysia enthusiastically engaged in the ongoing conversation and several times overcame her aversions to unfamiliar foods.

To understand why Malaysia participated differently during small-group activities than during big-group activities, I did additional analysis. I analyzed Enactment #1 and Enactment #2 to identify factors that seemed to foster participation when participants were highly engaged and then analyzed episodes during Enactment #2 when Malaysia was less engaged to identify factors in addition to her own preferences that may have inhibited her participation. This analysis suggests ways that activity structures, facilitation, and distribution of resources fostered and inhibited sensory and social engagement.

In this chapter, I show how placement and availability of materials (material configurations) and setup of the learning space (physical configuration) impact both each other and the social configurations (arrangements of participants and facilitators) that form. Since the physical configuration of the learning environment impacts the ways materials can be laid out and the affordances of social configurations for easy social interactions, I will begin my discussion with physical configurations.

7.2 Physical Configuration

As I looked across the two case studies, I noticed that participants had more sensory and social experiences when the individuals in a small group were closer together, and when participants could see and hear beyond their small group. I also noticed that participants had fewer sensory and social experiences when they were separated from individuals in their own groups or other small groups and that the degree to which participants were able to have sensory and social experiences varied, based on the social configurations within and across groups. The data from the two case studies highlighted the differing small-group social configurations that developed in the two enactment learning environments that were each physically configured differently (Figures 7.1 and 7.2). Room size, shape and function determined the layout of cafeteria tables in the space. This observation suggested that the extent to which participants were able to engage in sensory and social experiences that promoted their participation and learning may have been shaped by how the learning environment was physically configured.

Enactment #1 took place in an all-purpose atrium that served as a cafeteria for the students. We arranged three cafeteria tables in a U-shape with two groups working at each of the side tables, as shown at the bottom of Figure 7.1. Participants were in close spatial proximity to one another and oriented facing toward each other. In this physical configuration, participants easily engaged in continuous monitoring and attended to verbal cues. The configuration during big-group discussions in Enactment #2 was similar. Participants sat around a large table, close to each other, close to materials they were examining, and facing each other in a semi-circle (the large table at the center top of Figure 7.2). During big-group activities, Malaysia participated similar to the boys in Case Study #1; she monitored the behavior of other participants and the foods on the table, and she attended to discussion.

Though the actual configurations during small-group activities in Enactment #1 and big-group activities in Enactment #2 were different, they have in common that participants could see and hear each other, and they provided the proximity to and accessibility for participants to see materials they are engaging with and artifacts they had created. Participants engage around a common work surface. I refer to this type of physical configuration as a *centralized configuration.* In the small-group configuration of

Enactment #1, group members could easily see and hear each other and their materials and artifacts and the participants, materials, and artifacts of the group next to them. The big-group configuration of Enactment #2 was similar; participants could see and hear each other and all the materials and artifacts brought to the common work surface.

Small-group activities in Enactment #2 had a different configuration. Enactment #2 took place in a home economics classroom, designed with six separate kitchen facilities. Furthermore, each kitchen facility included a variety of work surfaces – several counters, the stove, and a work table. Multiple work surfaces allowed participants in each group to spread out and conduct procedures separate from other participants. This configuration inhibited monitoring of others and artifacts, inhibited hearing and attending to verbal cues from other participants, and inhibited easy social interactions among participants.

I refer to configurations with several places for engaging in activities as *decentralized configurations*. In decentralized configurations, participants are positioned farther apart and oriented away from one another, limiting collaboration and sharing of experiences within and across groups. Because I never saw a decentralized social configuration during Enactment #1, I hypothesize that decentralized configurations are more likely to form in physical environments that have multiple work surfaces.

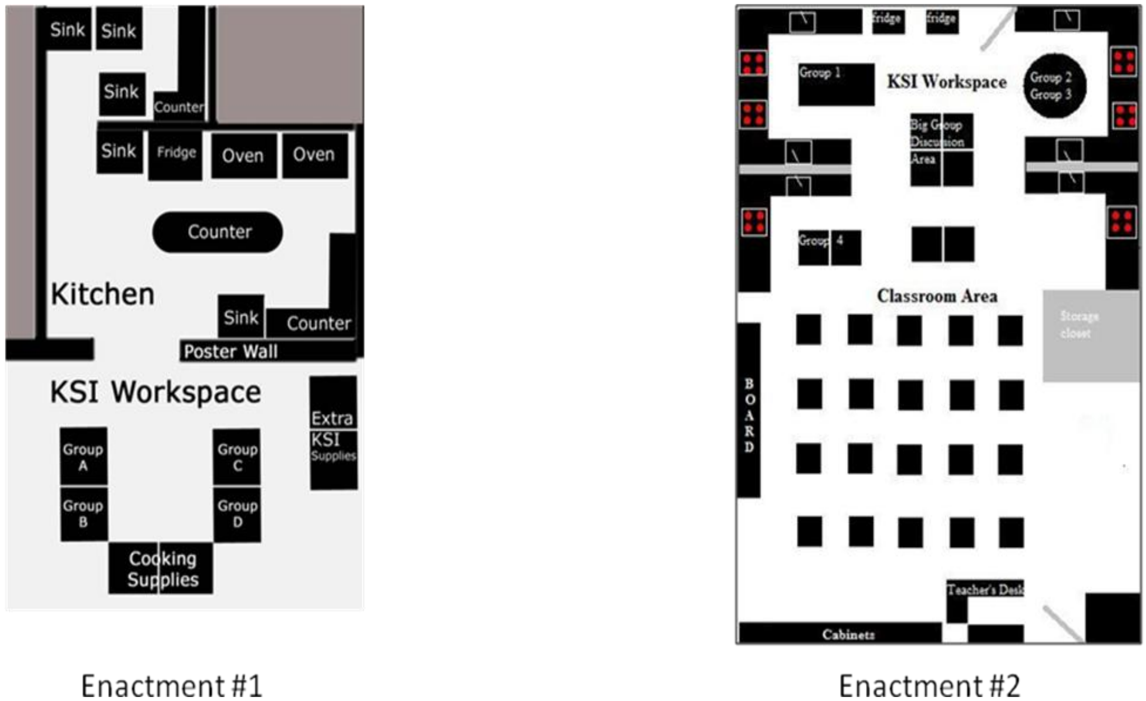


Figure 7.1: Environmental Configurations

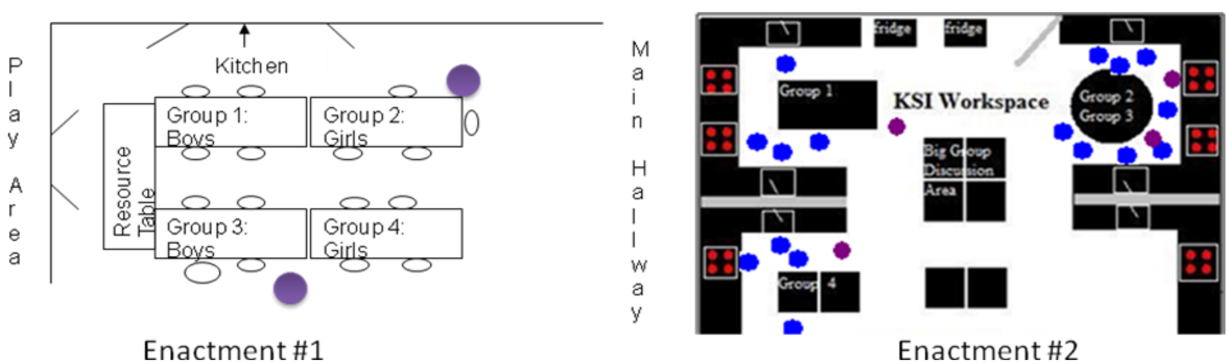


Figure 7.2: Arrangement of Small Groups

7.3 Social Configurations

7.3.1 Overview

I also noticed possible influences of social configurations on the sensory, social, and cognitive engagement patterns I found in the two case studies presented in Chapters 5 and 6. In centralized physical configurations, social configurations were also more centralized; participants engaged with those they could hear and see, and because they could hear and see each other, social interactions between and across groups tended to be common and fluent. In decentralized physical configurations, social configurations were also decentralized. Participants had to make more of an effort to interact with each other. Overall, I noticed that the structure of the physical configuration of the learning environment influenced the formation of small-group social configurations in a way that affected the availability of visual or auditory opportunities for participants to see or hear what others are doing, how artifacts are changing, and to gain exposure to important or interesting phenomena.

7.3.1.1 Social Patterns in Centralized Physical Configuration

Across both case studies, I found that centralized physical configurations promoted social interactions intended by the KSI design. Participants were close enough to each other to easily listen and talk to each other. They also had common experiences to talk about, as these configurations provided clear lines of visual and auditory access that draw attention to important artifacts and phenomena of interest. The clear lines of visual and auditory access allowed participants to have these interactions while participating in their own roles.

Clear lines of visual and auditory access provided participants with the opportunities to listen and talk to each other also led participants to be knowledgeable about entire recipe and experiment preparation processes, even parts they had not performed themselves. This allowed participants to be able to reflect individually and collectively. In addition, seeing and hearing what others were doing allowed them to experience phenomena that they discussed later in the big-group discussions and reasoned with later.

<u>7.3.1.2 Social Patterns in Decentralized Physical Configurations</u>

On the other hand, decentralized physical configurations fostered highly individualized experiences and prevented participants from having access to the experiences intended by the design. These configurations limited lines of visual and auditory access and impaired opportunities for participants to see and hear what others were doing and saying, major disadvantages for sensory, social, and cognitive engagement. Because Malaysia's group in Enactment #2 (Chapter 6) took on the shape of this type of configuration, she experienced only some parts of the recipe preparation and only some of the important phenomena, resulting in an inability to reflect on the recipe preparation process in its entirety. Because she often missed auditory and visual cues that highlighted the phenomena of interest, she could reflect only on activities she had performed herself.

7.3.2 Examples of Social Configurations that Promoted Engagement

Figure 7.3 shows an example of a centralized small-group configuration from Case Study #1. Notice that each group member's orientation was toward the single work surface, and the resulting horizon of observation, with both lines of visual and auditory access, was shared among the group members. In this centralized configuration, where the activities took place on a single work surface, each individual enacted the tasks associated with his/her role, oriented in a way that allowed other participants in the group to listen to, observe, or participate in what others were doing.

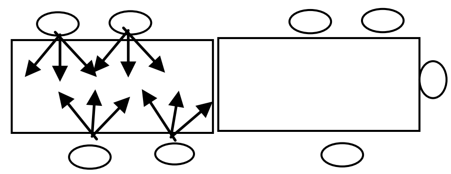


Figure 7.3: Participants' Orientation and Horizon of Observation in a Centralized Configuration

Overall, a centralized configuration fostered the following patterns because it offered participants clear lines of visual and auditory access:

Sensory Engagement

- Continuous monitoring and attention to verbal cues promoted seeing and noticing physical changes in the recipe, even when participants were not directly involved in the preparation when the change occurred.
- Continuous monitoring and attention to verbal cues also promoted opportunities to position themselves to gain more firsthand tactile experiences that allowed them to develop memory of textures and consistencies of recipes prepared over time, through recipe iterations, and for different recipes.
- Moreover, continuous monitoring and attention to verbal cues also promoted an overall awareness of the recipe-preparation process through both firsthand and secondhand experiences that promoted shared experience and individual and collective reflection.

Social Engagement

- The sensory engagement patterns identified above were also used by groups as part of their social engagement patterns
    - Noticing what others were doing, and checking actions and material interactions against the recipe;
    - Asking each other what they should be doing, or if their current action or trajectory was correct;
    - Sharing with others what they knew or had just learned;
    - Becoming curious based on the verbal cues of others' interests;
    - And vocalizing aloud what one was doing, recipe-reading, and discussing what was next, and why, while enacting the action(s) that allowed participants to position themselves.

As I highlighted in Case Study #1, when participants were able to have this extent of sensory and social engagement, they engaged more deeply cognitively. Having these interactions and experiences allowed participants to talk about the changes their foods had undergone and the processes used to create their recipe. These experiences were also important in (1) building their foundation for understanding the science explanations; (2) noticing changes in appearance, taste, and tactile characteristics in new recipes, as compared to their previous experiences with the same recipe; and (3) building an ability for revisiting the science content, applying the science content, and later, being able to talk intelligently about it.

These same sensory, social, and cognitive patterns were seen during small-group activities in Case Study #2 when the physical configuration was a single work surface that facilitated a centralized social configuration. However, they did not endure for any significant period of time, happening only while measuring, early in preparing a recipe, and while assembling a dish for final presentation. Continuous monitoring that would have afforded the kinds of sensory and social engagement patterns seen in Case Study #1 never happened.

When participants were around a single work surface during big-group discussions in Case Study #2, however, the resulting social and cognitive engagement patterns of participants were more like in Case Study #1. I hypothesize that this is because the big-group social configuration in Case Study #2 allowed Malaysia and other participants to continuously monitor other participants and artifacts and to attend to verbal cues and conversations – the affordances that let participants in Case Study #1 so richly engage with each other.

In Chapter 5, Case #1, I presented several episodes where the patterns in interactions and experiences presented above were enacted. For the purpose of illustrating the points of this argument, I have selected a few of those episodes, to illustrate the role of centralized configuration in promoting the interactions and experiences we desired from the activities. The selected episodes were characteristic of the participation of the boys' group throughout the program in Case Study #1.

7.3.2.1 Affordances for Visual and Auditory Engagement in Centralized Social Configurations

The next several episodes highlight the affordances of centralized social configurations for promoting sensory and social engagement patterns identified in Chapter 5. In particular, I focus on the role lines of visual and auditory access between participants played in promoting sensory engagement patterns of continuous monitoring and attention to verbal cues; and the support these affordances and sensory patterns of engagement played in supporting participant positioning and activity coordination through recipe reading, sharing information and collective decision making, and collectively making sure recipes/experiments were carried out correctly.

In Episode 7.1, the boys are arranged around a single table in their typical configuration depicted in Figure 7.3. They are measuring sugar and putting it in a glass full of water as they carry out the procedures for preparing their yeast air-balloon water bottles. This episode was previously discussed in Chapter 5, Episode 5.7. In the previous discussion of this episode, I focused on the impact of the auditory cues of participants indicating their interest in what was going on in the glass each time a measure of sugar was added had when heard by other participants. I found that these verbal cues not only indicated one participant's interest but it also directed other participants' attention and piqued their interest as well. Thus, the initial verbal cue then encouraged all of boys to continuously monitor William who was adding sugar to the glass. In addition, it led them to both continue to observe and discuss the phenomenon and then make predictions about what might happen next. Having seen the yeast move around in unexpected ways, they were now prepared to build an understanding of yeast as an organism.

In this discussion of Episode 5.7 (Episode 7.1 in this chapter), I focus on the visual and auditory affordances of the workspace, the arrangement of the boys in this workspace, and the artifacts, and I discuss they ways that this social configuration promoted the participants' sensory engagement.

Notice that the boys all stand around the table and watch as William measures and pours two teaspoons and two tablespoons of sugar into the glass of water, the boys are focused. The focus of their attention is denoted by their verbal cues of surprise, interest, excitement, and anticipation. Notice that after William measures the first teaspoon, Craig adjusts his positioning, crouching to look at the glass from the side. is the transluscent glass affords this view. Notice that after seeing Craig adjust his position, the other participants mimic him and adjust their positions to get a closer look. However, before William measures the second teaspoon, all the boys have readjusted their position to get an aerial view of the sugar being dumped into the water. As William is measuring the third amount of sugar, KJ points his index finger and extends his arm and moves his hand in a circular motion over the top of the glass cup with the yeast, water, and now sugar. KJ rebuts William's statement that the sugar simply sunk and suggests that the sugar turned over. Craig reminds William of the amount of tablespoons of sugar to be added. They then watch as William pours in the last tablespoon of sugar. William exclaims prior to pouring in the sugar that, "this is going to be big!"

Episode 7.1 (Cross Reference Episode 5.7)**: Session 1 - Case Study #1**
39:32
William: [Measuring the sugar]
Craig: "OK we're going to do that 4 times."
William: "Yes, Craig."
Craig: "So do that twice. Then use the tablespoon."

William: [pours in the 2^{nd} teaspoon]
Craig: [After William finishes pouring in the sugar] "Whoa!"
KJ: [let out a noise of excitement and amazement]
Brett: [with his mouth wide open] "Wow."
Craig: [moves to look at the side view provided by the translucent glass]
All: [move back to get a better look at the mound of sugar, William poured in sinking to the bottom]
William and Craig: [come back toward the table]
Brett: [His mouth is still wide open with amazement.]
KJ: "Awesome."
William: "That sunk."
Brett: "That was cool."
William: [recovering, goes back to measuring the sugar] "Two tablespoons of sugar." William: [goes back to measuring the sugar]
KJ: [points his index finger and extending his arm and moves it in a circular motion over top of the glass cup with the yeast and water and now sugar] "No, no it turned over." Brett: "That was weird."
Craig: "That would be one, William."
William: [pouring in the sugar]
All: [They all look at it again.] "Oh!!!"
KJ: "And then the yeast comes up."
William: [pouring in the tablespoon and leaning over the table] "This is going to be big." [He does this with his mouth wide open.] "D'oh! "
KJ Brett, Craig, and Ms. J look on.

From this transcript, one can see that this configuration makes it easy for the boys to see what is happening with their fellow group members and the artifacts on the table. Furthermore, they were able to hear each other's reactions as William poured the sugar into the glass and recognize that what they were seeing was interesting and others were interested as well. The centralized social configuration afforded clear visual and auditory lines of visual and auditory access and a shared horizon of observation, making it easy for all participants to attend to and continuously monitor what others were doing and the changes in the artifacts and to attend to verbal cues.

In addition, the continuous monitoring and verbal cue pattern were further supported by the affordances of the clear glass, in that it afforded multiple viewing angles and allowed all the boys to see the transformation of the yeast and sugar in the glass. Seeing that the sugar dropping into the glass dispersed the yeast already at the bottom of the glass piqued all of the participants' curiosity. This piqued curiosity prepared them for an explanation about yeast eating sugar during the cross-group conversation, which we will look at in a moment.

Like Episode 7.1, Episode 7.2 took place during Session 1, while participants were preparing the yeast air-balloon experiment. This episode was previously discussed in Chapter 5, Episode 5.6. In the previous discussion of this episode, I focused on how the impact of continuous monitoring of other people within their group, helped them maintain an ongoing knowledge of the procedures they were enacting and the location and appropriateness of materials. In this discussion of Episode 5.6, Episode 7.2 in this chapter, I focus on the role the centralized social configuration played in allowing the boys to maintain close-spatial proximity to one another throughout the preparing of the recipe and experiment. This promoted the group's awareness of the recipe/experiment's state of preparation and status of materials and facilitated the group's activity coordination.

In Episode 7.2, Craig was standing on one side of the table while Brett and KJ stood next to each other across the table from Craig. The three boys were oriented facing each other and their focus was on each other and the artifacts on the table. When William returned to the table, he stood next to Craig, at the short side of the table adjoining the two sides of the table the other boys were standing at (see Figure 7.3). Keep in mind that the boys have maintained their placements and this social arrangement around the table from when they were preparing the recipe. In general, they continue to maintain this social configuration throughout their participation in the program. In the description of this episode, notice the orientation of the participants and the artifacts and where participants' attention is focused.

In Episode 7.2, during the group's setup of the yeast air-balloon experiment, Craig read the experiment procedure and then attempted to gather the needed materials: balloon, warm water, yeast, sugar, and a water bottle. Each of the boys tried to help Craig locate and acquire the needed ingredients: Brett and KJ identify for Craig the correct balloon out of the two balloons the group initially received (Prior to this episode the group decided to use the one that Brett had been repeatedly blowing up throughout the experiment preparation process.) William worked to get the group warm water to activate the yeast for the experiment setup. Notice throughout this episode that Craig Brett, and KJ are oriented around a single work surface and that all the participants are continuously monitoring what each other are doing and talking and listening to each other. In addition notice that while Craig is coordinating the group's activity using the experiment procedure and the sheet is on the table in front of Craig, KJ and Brett are working on the same surface they have visual access to it and sometimes look at it.

Episode 7.2 (Cross-Reference Episode 5.6): Session 1 - Case Study #1

36:50
Craig: [Picks up a balloon on the table] "Which balloon has been blown up?"
Brett and KJ: [The two boys are standing next to one another across the table from Craig. They say simultaneously] "This one."
Brett: [Shaking the balloon that is in his hand]
KJ: "The one that Brett's holding."
William: [Comes in with the measuring cup of water] "It's 122."

37:15
Brett: [Continues to blow up the balloon]
William: [Looks on as Brett Blows up the balloon]
KJ and Craig: [Look at the experiment procedure printed on a sheet of paper, which is still oriented directly in front of Craig]
Craig: “We…” [Then, with emphasis and exaggerated hand motions] “Make sure, [Repeats with increasing volume] MAKE SURE, [Looking at William and points to the experiment directions] it’s between 105 and 115.”
William: [Takes the measuring cup and walks out of view of the camera to the kitchen]
Craig: [Continues to read and trails off as he realizes William is gone] “If the water is too hot add a little hot and cold water and stir until…”
KJ: [Look at the experiment sheet]
Brett: [Still blowing up the balloon, has now moved closer to KJ]

37:33
Craig: [Looks up] “How much time do we have left?”
KJ: “About two minutes.”
Craig: [Looking up, says to Brett] “Let it go.” [While reaching across the table to squeeze the air out of the balloon]

Brett and KJ had an awareness of the balloons’ histories, and this awareness was made possible by the fact they had been standing close to one another throughout the session and KJ been watching Brett throughout the experiment-preparation process inflating and deflating the balloon. In addition, notice that KJ was not actively performing experiment preparation tasks, but he was still able to answer questions about the appropriate materials to use (i.e., correct balloon 36:50) and the amount of time left for the dough to rest (37:15). He knew this because he was watching as others performed their tasks, and because he took an active role in monitoring the activity of the group against the directions (37:15). It seems that KJ was able to continuously monitor all of these different activities because he was in close proximity to the other participants. In general, I noticed that when the boys weren’t actively doing an activity task themselves, they were still watching what others were doing or looking at important artifacts. For example, recall that when William was finished with getting the water for the experiment to the right temperature that he began watching what the others were doing (37:15).

In addition, notice the fluidity of participation of all the group members as they carried out the experiment and coordinated their activities. For example, recall William's participation in the group as he tried to get the water for the experiment within the correct temperature range. He moved back and forth between the group's workspace and the kitchen area (off camera) to get the water, and when he arrived back to the table with the water he announced the temperature of the water and placed the cup on the table. Also recall that Craig was preparing other parts of the experiment setup when William announced the temperature of the water. While Craig didn't respond immediately to this announcement, when he returned back to reading the experiment procedure a few seconds later, he recognized that the temperature of the water that William measured was incorrect and brought this to William's attention by adding emphasis to the reading of the appropriate temperature range of the water. Then recall that William picks up the measuring cup of water and walks back to the kitchen before Craig can finish reading the experiment procedure instruction. This type of activity coordination and catching and correcting of mistakes, two social engagement patterns identified in Chapter 5, was one of the advantages of multiple people attending to activities happening at the table. This was possible because all these participants' interactions were open and visible to all at the table because of the close proximity they maintained throughout the activity.

Overall, this episode highlights the role close spatial proximity of participants working around a single work surface plays in affording participants opportunities to continuously monitor the activities of others and to keep track of important artifacts. This allowed participants to gain an awareness of the experiment procedure and the status/state of materials and resources, to catch mistakes, and to coordinate their activities.

Close spatial proximity also played a role in allowing participants to attend to the verbal cues of other participants that signaled the direction of the activity and to use those verbal cues as means of positioning themselves to participate in the activities. Episode 7.3 highlights participants' attention to verbal cues signaling the direction of the activity was afforded by close proximity of participants to one another and clear lines of visual and auditory access which further supported participants' visual continuous monitoring of activities and others.

Episode 7.3 also took place during Session 1, while participants were preparing for the yeast air-balloon experiment. This episode was previously discussed in Chapter 5, Episode 5.12. In the previous discussion of this episode, I focused on the impact of continuous monitoring of other people and artifacts fostered opportunities for giving and receiving advice and correcting one another within the group. In this discussion of Episode 5.12, Episode 7.3 in this chapter, I focus on the role that participants working in close proximity to one another had in furthering participants' attention to verbal cues, their ability to seek out, acquire, and retain possession of essential materials, and their ability to position themselves in activities.

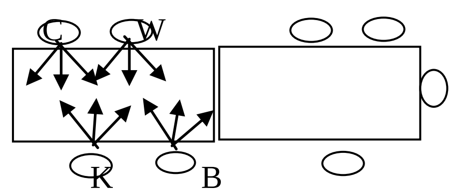


Figure 7.4 - Episode 7.3 Social Configuration

In Episode 7.3, the boys are arranged around the table with Craig and KJ standing across from one another on either side of the table closest to the end of the table and William and Brett standing across from one another on either side of the table (see Figure 7.). This arrangement allowed the boys to attend to the verbal cues of other participants about the status of different tasks, the direction of the activity, and responsibilities each person wanted to take on.

Episode 7.3 (Episode 5.12)**: Session 1 - Case Study #1**

37:45
William: [comes back to the table with the water] “Craig, it…” [Voice trails off].
Craig: “OK” [with a relieved sound in his voice]
Craig: “OK, add, the… Where’s the yeast?”
KJ and Craig: [look around the table]
William: [walks to the other side of the table closer to Craig and KJ and looks] “Where did you put it?”
Craig: “Yeast” [like you call a person’s name to come; and then points to the table off to the side of the girls’ group]
William: [runs and gets it]
Brett: [is sill blowing up the balloon]
Oriana: [ethnographer, comes over to the table and waves in a stopping motion toward Brett]
Brett: “Is that good?”
Craig: [takes the yeast from William] “OK I’ll do it.” [He has the measuring spoons in his hands.]

38:00
Craig: [looking at the experiment sheet, then to the measuring spoons in his hands] “Two and one fourth.”
William and KJ: [look at the experiment]
William: “It’s half a tablespoon.”
Craig: “No, it’s one teaspoon.”

38:25
Craig: “Is this yeast?”
KJ: “its bread machine yeast, Craig.”

Craig: [with a little bit of sass] “It’s supposed to be Dry active Yeast!” [While he measures the first teaspoon; then with measured yeast says anxiously] “Where do I put it?”
William: “Right here.” [Pointing to the liquid measuring cup]
Craig: “No. You’re supposed to put that in the cup.”
KJ: [picks up the cup, then places it back down on the table in front of him]
William: [He walks around toward KJ with the liquid measuring cup and the thermometer in his hand. Then he places the cup on the table next to KJ.] “It’s about 110 degrees.”

38:56
KJ: [bent over the table looks into the cup] “It’s going to pile up like an island.”
Craig: [Still measuring the yeast and pouring it into the cup of water, he then places the ring of measuring spoons down on the table and looks for the ¼ spoon.] “1/4.”
William: [at the same time that William comes back to the table saying] “What do we do now?”

39:09
KJ: [looking over at Craig trying to find the ¼ tsp measuring spoon] “You can use 1/8th two times.”
Craig: “Good point.”
KJ: [as Craig picks up the measuring spoons] “I see the ¼.”
Craig says, “I found the ¼.” [As he’s scooping out the yeast]

39:32
William: [looks down at the experiment sheet after Craig finishes pouring the last bit of yeast in] “Now what’s next?” [Then he begins reading as he moves his body closer to the table.] (Put the text that he reads here) [Then he hesitates.]
Craig: [bending down over the experiment sheet with emphasis and pointing] “Yeast! And sugar!” [Lowering his tone to a reading tone he says] “Stir until dissolved.” [Then he summarizes.] “So the sugar. Sugar. One. Two tablespoons of sugar.”

This episode shows the many different ways the boys notified each other about the activity, the available task roles, and the task roles that were already taken. They did this predominantly through use of verbal cues. For example, when William returned with the correct temperature water, he directed his declaration about the water temperature to

Craig, who earlier caught the mistake. Later, Craig announced to the group that he needed the yeast and William and KJ began looking for it. Craig visually located the jar and William sought it out and brought it back to the table. Craig then took the yeast from William and declared that he would be completing that step. Attention to these verbal cues was made possible by the open line of communication afforded by the centralized social configuration this group maintained.

When the boys talked out loud about what they were doing, as they went along, it allowed the other boys at the table to participate in the experiment procedures and recipe preparation processes. Even when the other boys played only supporting roles, these roles were important because they allowed all the group members access to the activity. These experiences allowed them to later reflect on the what they had done and phenomenon they had observed.

In particular, Craig's verbal articulation of the instructions motivated the others to seek out and acquire essential materials for the completion of the experiment procedure step. The clear lines of auditory access provided by this social configuration allowed participants to hear and respond to verbal cues about the direction of the activity as they located key items. The close proximity of participants to one another made it easier to maintain dynamic communication and interaction and not just to simply observe what others were doing. Thus, clear lines of visual and auditory access and the close proximity of participants to one another allowed participants to position themselves to be more actively involved in the preparation activities.

Another important thing to notice from episode 7.3 was the efficiency and fluidity of the group. Recall that the boys shared a single workspace and at any given time, multiple activities were simultaneously conducted around a that surface. For example: William ensured that the water was the correct temperature, Craig measured the yeast, and Brett stretched out the balloon making it easier to inflate later. However, each participant had visual and auditory access to all of these interactions. Also notice the rapidity of verbal exchanges, and all of the non-verbal material interactions these participants were having. For example, they read the experiment's instructions aloud, made declarations about what part they would perform, and notified each other of necessary tasks. All of these things became affordances for experiencing and participating in the experiment preparation process.

Also notice that they cohesively moved from one step to another. Recall from Chapter 5 that recipe reading and asking about the next recipe step were supported by continuous monitoring and attention to verbal cues in Case Study #1 where the group members worked in a centralized configuration. Participants engaged in social engagement patterns that allowed participant positioning and activity coordination; sharing what participants had learned; collaborative decision-making and catching and correcting mistakes.

Next, I want to highlight the role that centralized social configurations had on fostering information-sharing and collaborative decision-making among participants. Episode 7.4 took place during Session 5, a Retry Day, in which the boys decided to alter a cookie recipe, substituting yeast instead of baking powder. They wanted to see whether yeast would make the cookies rise more than the other leaveners they had tried. This episode highlights Craig's leadership and communication skills as he openly shared information and encouraged mutual decision-making with his group members. The physical orientation of each participant allowed for easy and open interaction and communication amongst the group members.

Episode 7.4 (Episode 5.13): – Session 5 - Case Study #1

22:53
Craig: [goes over to his group and shares with his group the conversation he had with Christina] "Should we put the yeast in a separate bowl from the wet and dry ingredients?"
Brett: [walks away as Craig begins talking]
KJ: [comes back to the table]
William: [focused on another ingredient, begins talking over Craig]
Craig: "William, listen! We have to make a decision about what to do."
23:13
Craig: "Yeast and water or yeast, water, and sugar?"
William: [totally distracted by something in a container and interrupts Craig again while Craig is talking]: "This is the coolest thing ever."
Brett: [at the same time as William's outburst, responds to Craig] "Yeast and water." [Inaudible over William talking, which shifts the group's attention to William]
23:21
Craig: [holding his hands up to his ears in a sign of frustration to drown out what William is saying] "Guys, we need to figure this out now."
23:39
Craig: "We have to decide if we are going to put the sugar with the yeast and water or if we are going to put the yeast with the dry ingredients. She said we have to have three bowls: one bowl for the dry, one for the wet, and one for the yeast and water."
23:45
Brett: "I think just the water and the yeast."
Craig: "I think the water, the yeast, and the sugar because the sugar needs the water to wake it up. I mean the yeast needs the water to wake it up and then the yeast eats the sugar."
KJ: [Inaudible exchange between Craig, William, and KJ. KJ raises his hands above his head enthusiastically. He later repeats this gesture and the ending discussion, which denotes gas escaping.]
KJ: "So we put the sugar with the dry stuff for the dough."
24:06 [end]

Notice that when Craig returned back from talking with Christina, he tried to garner his group's attention. Each of the group members were actively engaged in other activities when he arrived, so they did not initially acknowledge him. Brett was walking away from the table, KJ was returning back to the table, and William was looking at one of the ingredients in a container. Thus, Craig repeatedly tried to get their attention using verbal cues. What he figured out was important enough to the success of the recipe, he thought, that it was essential to share with his teammates. When he gets their attention and they all settle into their positions around the table, he began talking to them about his conversation with Christina and the decision they needed to make about where to place the yeast and where to place the sugar.

This episode shows how Craig, a leader of and resource for his group, shared what he knew with other group members and got them to make decisions as a group. This was also indicative of the group's pattern of sharing ideas with one other, made possible because they'd been in close proximity to one another and physically oriented toward one another for most of the episode which created clear lines of visual and auditory access for the participants to see and hear each other.. And it had become a common pattern for everyone to ask what was going on in/with a recipe.

7.3.2.2 Affordances for Cognitive Engagement in Centralized Social Configuration

Thus, both sensory and social engagement patterns that promoted learning in Case Study #1 were promoted by the close proximity of participants around a single work surface and the clear lines of visual and auditory access, affordances of a centralized social configuration. In this section, I will show that the experiences fostered in this centralized social configuration further prepared participants to reflect on these experiences- even experiences they did not directly have themselves.

During Session 5, Episode 7.5, participants made pizza for a second time, varying the amount of yeast. Despite very little dialogue, each participant in this group was engaging in some level of reflection, and building on the reflections of others.

Episode 7.5 (**Episode 5.17)**: - Session 5 – Case Study #1
1:03:08
> After cleaning up their space, the boys look at their papers (Planning and results sheets at their table)

1:03:45
> Craig: [gets up and jots notes down on the poster wall]
> Brett: [joins Craig at the poster wall]
> KJ: [stays at the table writing on the planning sheets]
> Craig: [hangs the pen on the poster wall and then walks back to the table]
> Brett: [looks at what Craig has written and walks toward the poster and gets the pen and writes something]

1:04:16
> [Craig and William look through the planning and results papers and write down something on one of the pieces of paper on the table]

Notice in this episode, that when Craig gets up to jot notes on the poster wall, that Brett follows. The spatial proximity of these participants and the available lines of visual access in their social configuration around a single table allowed the boys to observe the movement of group members around the workspace. This helped to promote a collective reflection process even when participants were acting as individuals.

This social configuration allowed for group members to verifying each other's work. In this instance, Brett was checking over Craig's recorded observations. Later, we see Craig and William checking over KJ's observations on the planning sheets. While we couldn't guarantee that all configurations like this would result in similar outcomes, this analysis showed that this group's method of error checking matched their patterns of reading the recipe aloud and group collaboration.

The centralized social configuration of this group provided the participants with a collectively shared experience that allowed all of the participants to talk interchangeably about it. In Episode, 7.6 from Session 8, it was clear that all group members were able to share in the explanation of how their cookies with yeast recipe was prepared. It seems that the experiences and ways this group had collaboratively worked together throughout the recipe preparation process around a single work surface afforded this knowledge. The recipe was collectively prepared by all of the group members, with some group members being more heavily involved (i.e., Craig and Brett), and others looking on and providing supportive roles by getting ingredients and other resources as they were needed. Notice as you read this episode how the participants recount the cookie preparation process, fluidly shifting between participants, with participants sometimes talking at the same time.

Episode 7.6 (Episode 5.19): Session 5 - Case Study #1 - Ending Discussion
Christina: "Brett."
Brett: "So we…"
Christina: "So tell us which ones are your cookies?"
Craig: "The white ones."
Brett: [pointing to the cookies]
Brett: "We took out the BS and BP and put in yeast."
Craig: "And we added water to the recipe."
Brett: "Because we need the water to wake up the yeast."
Craig: "Then we put the yeast and the water in a separate bowl from the dries and the wets. Then we mixed it all together and it sort of turned into dough but we couldn't knead it."
Brett: "We used three bowls because we did one for the yeast because we didn't want to add that one yet because we wanted to capture the carbon dioxide."

CMG – “OK.”
Craig – “Then we had a bowl for the wet ingredients and for the dry ingredients.”
KJ – “So stop bugging us about the three bowl stuff.”
CMG: “OK, so I hear that you used one bowl for the yeast and that you added water to the recipe to wake up the yeast. Then I hear something about catching the carbon dioxide. Tell me a little more about that.”
KJ: [KJ tries to tell her but as his mouth opens and before he can say anything Craig speaks over him.]
Craig: “Well if we put the sugar in with the water and the yeast it wouldn’t rise. Well it would but it (pause) then the carbon dioxide (pause) and the yeast would just expand and then it would be hard to mix.”
CMG – “So how did you avoid that then?”
Craig – “We used three bowls.”
Craig – “We didn’t put the sugar in with the yeast and the water; we put it in wit the dry ingredients.”
CMG –“OK, how did you mix this stuff together?” [Waiving her hands to denote mixing]
[Craig, Brett, and KJ start talking at the same time]
KJ – “We then put it in the bowl [using his hands to make a dumping motion]
Brett – “We mixed it.”
Craig – “We used…”
CMG – “So you just put in everything at the same time?” [Using hand motions to denote pouring in everything at the same time]
? – “No.”
KJ – “No. [Using hands] No we…” [He gets cut off]
Craig – “No we put the dry ingredients with the butter [this refers to the butter that was creamed with the sugar] and then we poured [makes a pouring motion with his hands] in the yeast and water.”
1:21:32
CMG – “And that does what? How does that capture the, capture your air bubbles?”
[KJ and Craig talking at the same time]
KJ – “The dry products…”
Craig: “Because the dry products make a...”
KJ – “Act as a balloon [making arm and hand motions to denote a balloon blowing up]
Craig – “Balloon.”

This episode demonstrates the ease with which participants stepped in and spoke over each other. The noticing, seeing, and observing that they were able to do while working around the shared work surface promoted common knowledge of the recipe preparation and the scientific reasons behind why they'd made the recipe changes.

To further substantiate this claim, recall the parallelism between the explanation given by Brett (in Episode 5.19 in Figure 5.7) and the explanation Craig gave during the small-group discussion earlier, after Craig had talked to Christina (excerpt from Episode 5.13 in Figure 5.7). The second set of text Episode 5.13 highlighted an issue the boys had in the recipe preparation process: They needed an extra bowl to enact their plan for capturing the carbon dioxide the yeast produced, and this meant that another group wouldn't have the full resources it needed. KJ's presence during the small-group activities gave him access to the three-bowl plan, which caused controversy with members of another group.

7.3.3 Examples of Social Configurations that Inhibit Engagement

In this section I will now present a series of episodes from Case Study #2, Enactment #2, at the New Hope Middle School where the KSI Program was held in a Home Economics classroom. The physical configuration of Enactment #2 had multiple work surfaces that distributed participants into social configurations that didn't allow them to see each other work. Thus, the lines of visual and auditory access in these configurations were limited or impaired, making continuous monitoring of others and activities difficult. In fact the physical configuration of Malaysia's group's workspace afforded the formation of eight different small-group social configurations over the span of a single session, Session 16.

These social configuration are shown in Figure 7.5 and developed when Malaysia's group were making the fruit tart. A key at the top of the figure identifies all of the key surfaces and materials on the surfaces. Each cell of Figure 7.5 depicts a kitchen layout with the counter signified by the blue line in an “L” shape, with a sink, laptop, stove top, hot plate, and another stove top. The eight configurations, “A” to “H,” are sequenced in the order that they occurred. Thus, to read them in chronological order, one reads from right to left and then down to the next row. In addition, each configuration is labeled with a description of the activity that was occurring at the time: planning, recipe preparation, or reflection.

Lastly, the cells in Figure 7.5 are labeled with a number in parentheses showing shifts in the configurations. For example, social configurations “A” and “B” both occurred while the group was engaged in planning. Social configuration “A. Planning (1)” shows that at first all three group members were clustered by the computer planning. Social configuration “B. Planning (2)” shows that while the group was planning, the social configuration changed, leaving the facilitator and Malaysia at the computer, while Candyce did things at the table.

Key: Laptop ; Hot Plate ; Sink ; Stove Top ; Table ;
Facilitator ; Participants: Malaysia ; Candyce ;

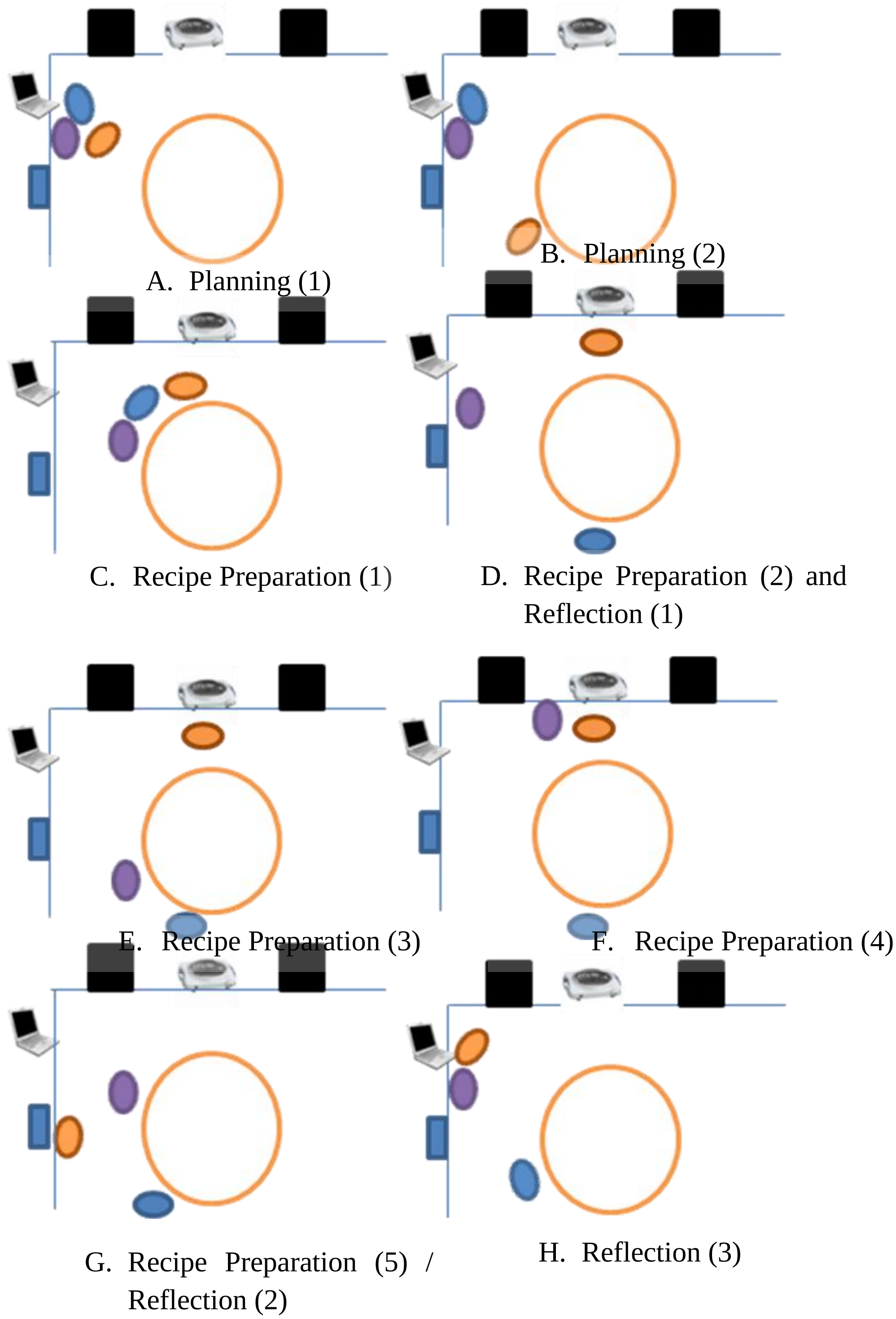


Figure 7.5: Changing Social Configurations

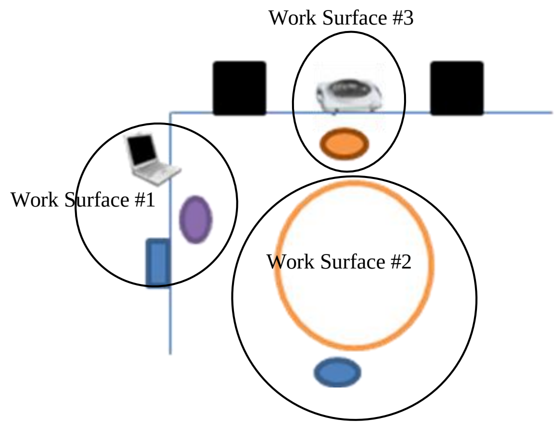


Figure 7.6 Work spaces for Enactment #2, Case Study #2

There are several things to notice about the social configuration of this enactment. First, I direct your attention to ways in which certain activities were sequestered to specific work surfaces based on the material configurations of the space (see Figure 7.6).

For example, on Work Surface #1, the counter with the sink and the laptop, participants engaged in recipe planning and reflection activities. The laptop was placed on Work Surface #1 because that was where the power outlet was located. Thus, Work Surface #1 safely provided power to the laptop without causing the tripping hazards that might have arisen if the laptop had been placed on the table, Work Surface #2.

Second, I direct your attention to Recipe Preparation, for which the group formed five different social configurations (see Configurations C-F in Figure 7. 5). Notice that recipe preparation activities first took place on Work Surface #2, with both participants and facilitator present (shown in C. Recipe Preparation (1)). As the recipe preparation process progressed the three individuals moved to working on three different work surfaces (shown in D. Recipe Preparation (2)). Then later on they formed several configurations of the facilitator with each one of the participants separately (shown in E & F Recipe Preparation (3) and (4)). Notice that very rarely did the group form social configurations with both participants working on the same surface, either over the hot plate at Work Surface #3 or cutting fruit at Work Surface #2 (not pictured).

Third, I direct your attention to the three configurations that characterize reflection (Configurations D, G, and H in Figure 7.5). Notice that there were three opportunities for reflection, all of which occurred when all of the participants were separated or in dyads. In either case, the reflection was usually confined to the two people who were talking. This seemed to be due to impaired hearing caused by the distance between the work surfaces and the overall noise level of the environment that prevented the third person, usually Malaysia, from hearing these conversations.

However, the most important thing to take away from the overall set of social configuration diagrams in Figure 7.5 is that during a single small-group activity session, the group transitioned into over 10 different social configurations while planning, preparing, and reflecting upon the recipe they were perfecting. Moreover, they spent the majority of their time in Configuration D, where each person was working individually and oriented away from what others were doing. This was significant, because having participants distributed across multiple work surfaces limited the lines of visual and auditory access open in this group and severely limited opportunities for participants to have overlapping horizons of observation. Hutchins (1995) defines "horizons of observation" as the lines of communication and limits on observation of activities of others by a single person. Thus, I define overlapping horizons of observation as the intersecting lines of multiple participants' visual and auditory access to activities and each other working.

In the next few subsections, I present episodes that highlight the effects of these social configurations and the effects the changing social configurations had on participants' interactions, and experiences. Notice that the intended goals of the activities were still achieved, but due to the social configurations, the intended activity experience was limited to the participant who viewed the phenomena firsthand. In addition, notice that when the social configuration was such that all three participants were working around a single surface, some of the benefits of the centralized social configurations (e.g., checking if the ingredient was correct, if the amounts were correct, and if the measuring procedure was appropriate) were obtained. However, when the three are working on separate work surfaces, important observations about the state of the recipe artifact were missed. Thus, I have noted in the transcripts when participants are together and apart and when the group moves between centralized and decentralized social configurations. Since transitions between social configurations seemed to be initially driven by the small-group activity, I organize the presentation of these influences by activity.

7.3.3.1 Planning

Malaysia and the facilitator (JLK) primarily conducted the initial planning for the fruit tart. The goals they set for the dish then became a driver for the selection of the starch they used to achieve their goal (i.e., having the fruit tart filling's texture sufficiently thick to be able to cut it, and having the slice retain its shape). In Episode 7.7, notice that Candyce is initially a part of the planning as she stands around the computer with Malaysia and the facilitator (Figure 7.7 Planning (1)).

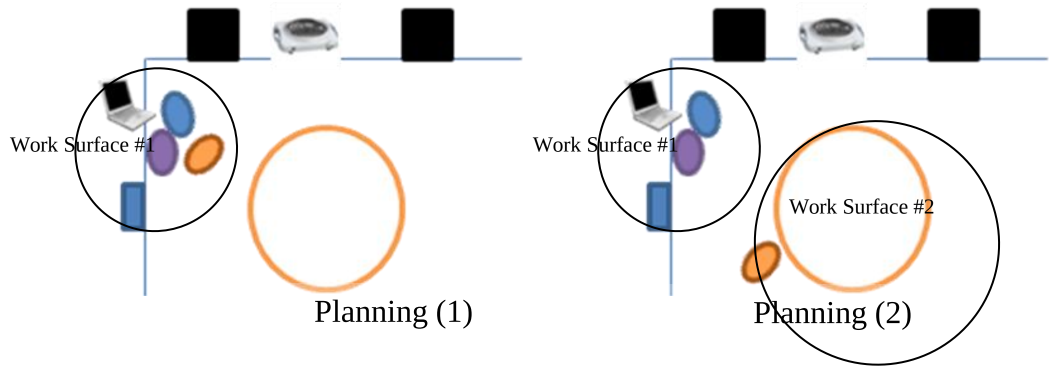


Figure 7.7 Social Configurations of Episodes 7.7 and 7.8

Episode 7.7 (Episode 6.8): – Session 16 - (Social Configuration – Apart)
JLK: [off camera] "OK, so let's see what we are supposed to do, OK? [Walking back onto camera and to the counter near the computer (Work Space #1) and looks down at a small stack of papers.] First of all, what [pause] [Malaysia and Candyce come into view of the camera and circle around JLK at Work Space #1] We are supposed to look at this." [Inaudible, but picks up the papers]
JLK: "Think in terms of [inaudible but bits and pieces suggest that they are talking about all the things they want their tart to turn out like in terms of five senses] "Smell." [Sniff]
Candyce: [moves away from the group to Work Space #2]
Malaysia: "Congealed."
JLK: "Sweet."
JLK: "We want it to look?" [Using descriptive words]
Malaysia: "Moist."
[Malaysia and JLK continue to discuss how they want it to turn out, they talk about using descriptive words, however most of this exchange is inaudible.]
Malaysia: "Are we making two of them?"

Although Candyce didn't say anything in the transcript of Episode 7.7, she was present for this portion of the conversation. However, as the planning process continued, Candyce roamed back and forth between Malaysia and the facilitator at the computer (Work Space #1) and the Central Table (Work Space #2) (denoted in Figure 7.7.- Planning (1) and Planning (2), together-then-apart). At times, Candyce left the small-group area altogether to gather ingredients. During these times, the facilitator tried to pull Candyce back into the conversation.

Episode 7.8 denotes Candyce's shift between the two social configurations. At the start of this next episode, Episode 7.8, Candyce was standing with Malaysia and the facilitator at the computer Work Space #1 and told them the starch she thought they should use, arrowroot (Figure 7.7 – Planning (1)). However, notice how she moves away from the group to look at ingredients on the central table in Work Space #2) (Figure 7.7 – Planning (2)).

Episode: 7.8: Together/Apart
Session 16
JLK: "Okaaaay here we go!"
Malaysia talks into the mic.
Candyce mentioned arrowroot as they're all at computer
[Candyce walks over with paper in her hand.]
Candyce: "Umm, the arrowroot, say arrowroot."
[Candyce roams again, picking up some of their ingredients and putting them down. Candyce walks back over to her group (at computer) and tells them something. They read recipe for a while they are still crowding at the computer]Malaysia: [(Inaudible) turns to Candyce and asks her some things.]
Candyce: where does the tart go[?]
JLK: "We're making it."
Candyce: – "Oh I thought we were making all the…" [Hand motions]
[Says because when they made something it came with whatever she just asked about]
Candyce leans in between JLK and Malaysia to point to something.

The other thing to notice about this episode is that although Candyce was gathering ingredients for the fruit tart, she didn't have a firm grasp on exactly what they were making. Part of this might have been due to the fact that she was moving around all the small-group workspaces, trying to gather materials and was thus moving in and out of the ongoing conversation Malaysia and the facilitator were having about the recipe and their goals. In particular, the lines of visual and auditory access were limited as Malaysia and the facilitator were oriented around Work Space #1 (sink and counter with the computer), which positioned their backs to Candyce, who was working at Work Space #2, the central table. Thus, Episode 7.8 denoted the inhibiting impact of the shifting together-then-apart social configurations of shared knowledge in this group.

Notice from these two episodes, Episodes 7.7 and 7.8, that Malaysia knew the group's goals for the texture, taste, and mouth-feel of the fruit tart custard/filling, and Candyce had knowledge of the ingredients and other tools they needed to prepare the recipe. Recall from Chapter 6 that Malaysia had a gap in her understanding of the process by which starches work because she'd started participating in the KSI Program during Session 15, and although actively engaged in the planning, she was only sporadically involved in the recipe preparation process.

7.3.3.2 Recipe Preparation

After the planning, the group transitioned into preparing the recipe. During the recipe preparation process, the social configuration shifted from the computer at Work Surface #1 to (the central table) located at Work Surface #2 (see Figure 7.8 and Episode 7.9). In Figure 7.8, notice how the group had similar patterns to the boys' group highlighted in the centralized within-small-group social configurations.

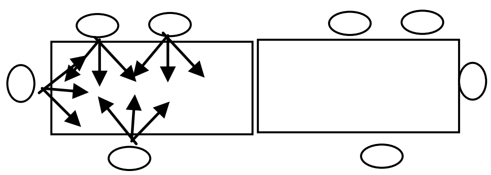
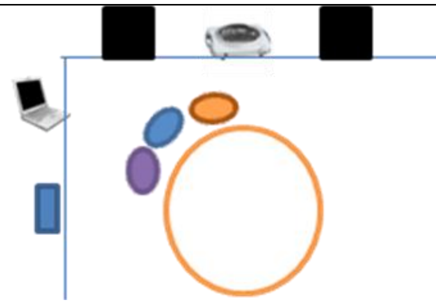
Case Study #1: Centralized Social Configuration	Case Study #2: Centralized Social Configuration
	 D. Recipe Preparation (1)

Figure 7.8: Together-Social Configuration

In Episode 7.9, notice the facilitator asking questions about the amount of sugar needed in the recipe and Candyce looking to see how much. Notice also that the facilitator was watching the girls as they worked and was helping them perform their tasks. While this level of facilitator support was not needed for the boys' group in Case Study #1 to engage in continuous monitoring and to attend to verbal cues, the sporadic centralized social configuration and facilitator support in Case Study #2 made it possible for Malaysia and Candyce to engage in these practices. Notice that here the girls took on recipe-reading patterns similar to the boys in Case Study #1. For example, notice that Candyce was monitoring the activity at the table and asking questions about what they should be adding next or announcing what they were adding next. The facilitator read the recipe aloud like the boys' group had in Enactment #1.

Episode 7.9: Checking (Together-Social Configuration)

JLK: “So who knows how to divide [egg yolks]?”
Malaysia: “I’ll do it.” [Volunteers]
Candyce: “Do you want the eggs separated?”
JLK: “Yes, they gotta get the yolks.”
JLK: [shows them how to divide the yolks]
JLK: “How much sugar?”
Candyce: [looks to see how much]
JLK: “A quarter cup of sugar.”
Candyce: “You said one fourth?”
JLK: “Right across the top.” **[As Candyce measures sugar]**
JLK: “That's not really full is it?” **[She moves around and shows Candyce how to measure it.]**
Candyce: “I thought it was something else we added.”
JLK: “No not yet.” [Reads next step in the recipe aloud.]
Malaysia: [stirs]
Candyce: [moves to go get arrowroot and **holds it in her hands and observes]**
JLK: “You wanted it to be smooth right? So is this smooth enough?”
Malaysia takes over the stirring.
JLK types in the computer.
JLK: “that good?”
Candyce gets tbsp, JLK gets paper towel for her to dry it - tells her she needs to dry it really really well.
Malaysia comes over with bowl, still stirring.
JLK: “It got smooth!”
Malaysia: “Very smooth, and my hands hurt!”
Malaysia wants to know how many they're making.
Candyce stands off to the side.

The pattern I noticed in this episode was of Candyce actively engaged in monitoring the preparation process, even though she was not enacting each procedure. This was much like what we saw with the boys’ group in Case Study #1. So the important feature in this episode was that the centralized social configuration in Case Study #2 that promoted these sensory and social engagement patterns was the same as the centralized social configuration pattern that promoted sensory and social engagement patterns in the boys’ group in Case Study #1. The essential difference, however, was that the boys in

Case Study #1 were always in this social configuration, while the girls in Case Study #2 were only in this configuration sporadically. When they were in this centralized social configuration, they had the same opportunities for participation that the boys in Case Study #1 had, and they took advantage of those opportunities in the same ways. One might say they were "at the right place at the right time," oriented in a way that afforded continuous monitoring of what was happening, and were thus able to enact a more fluid and collaborative recipe-preparation process.

Episode 7.10 provided another example of participants around a single work surface and the ways that the participants were reflecting as they worked in close proximity, which allowed them to hear each other. Moreover, notice that the participants were asking each other questions about measuring on several occasions. In addition, notice the way the facilitator was helping Candyce to measure the milk correctly, an event Malaysia was also able to see.

Episode 7.10: Session 16
Malaysia: [measures arrowroot] "I need to make it flat?"
Candyce: "Yes."
Candyce reaches in to do measurement.
JLK asks Candyce to mix the big bowl, instructs Malaysia to pour dry ingredients a little at a time
Candyce: [as Malaysia's pouring] "I can feel it getting thicker."
JLK: "Yeah?" **[Walks over to computer and types in, comes back leans between Malaysia and Candyce]**
JLK: "Oh this is gonna be nice ... you got this nice and smooth here."
[Goes back to computer and types.]
Malaysia talks about getting the lumps out.
Candyce looks into the bowl as Malaysia stirs.
Malaysia: "No air bubbles."
[JLK asks for some milk.]
Candyce: "I'll be back shortly." [Walks out]
Malaysia tells Sara [who comes over] that they're doing the simple stuff [Sara's group].

Candyce comes back with milk, JLK tells her one and a quarter.
Candyce stands off and measures then holds the glass up to check measurement.
JLK has her put the measuring cup on the counter, she leans over and checks the measurement, they all lean down to check the measurement. They keep doing it.
Candyce verifies that yep, it's the right amount.

This episode highlights the role that participants' working around a single work surface played in allowing them to form a centralized social configuration. Furthermore, it shows that in this configuration participants were talking to one another about the recipe and making sure everyone was doing things correctly. Similar patterns of continuous monitoring and checking to make sure that recipe tasks were completed correctly was consistently seen in Case Study #1. However in Case Study #2, the multiple work surfaces prevented the centralized social configuration from regularly occurring after the measuring activities were complete.

7.3.3.3 The Role of Materials in Influencing Social Configurations

The next series of episodes highlights the effect that shifting from a single workspace to multiple workspaces had on the social configurations that formed, the orientation participants took on in relation to the workspace at which they were working, and the level of focus their activity demanded.

Episode 7.11 shows that the three work spaces and the complexity of the recipe set the tone for the division of labor in the group and the ways that it shifted Malaysia, Candyce, and the facilitator into different places. Episode 7.11 begins with the facilitator, Malaysia, and Candyce standing around Work Surface #3, and the facilitator's attempt to get Malaysia to stir. But instead, Candyce ended up stirring and Malaysia moved to Work

Space #2 and sat at the table. In an attempt to re-engage Malaysia, the facilitator works with Malaysia almost one-on-one. Notice that Malaysia shifts between the Work Surfaces and eventually stirs the pot briefly, but when the fruit to top the fruit tart arrives, she shifts back to the table on Work Surface #2, Candyce remains on Work Surface #3, and the facilitator bounces back and forth between the three work surfaces. This social configuration becomes the normative configuration for this group.

Episode 7.11 (Episode 6.3 (3.14)) (Division of Labor):
Session 16
[The facilitator, JLK, tries to get stove to turn on, Candyce holds pot. They move to the next stovetop.]
JLK: [to Malaysia] "You gotta stir."
Malaysia: "So we've got to watch it?"
JLK: "Somebody's gotta watch it."
Malaysia: "I'll watch it, Candyce."
Candyce: [Candyce pulls up a chair to the stove and watches the pot while Malaysia and JLK are at sink doing something else. Candyce stands and looks in. Candyce moves over to emptied green bowls, peers in, stirs a little with spoon, and moves back over to the pot. It's not heating fast enough so JLK goes to get the hot plate and places it between the two stoves.]
JLK: "Stand by the hot plate."
Malaysia: [is standing at the sink not paying attention to this interaction]
Candyce: [Takes her seat again. Candyce picks up chips on table, puts them down, and peeks in drawer in kitchen sitting in her chair. Candyce walks around, comes back, peers in pot, bends over to look at burner, and walks around some more. Candyce puts top on milk. Then says something inaudible, she moves with milk off camera.]
JLK: [walks over to the pot]
Candyce: [quickly stands up in front of the pot]
Candyce: [sits back down in the chair, peers over across the room]
Malaysia and JLK are not shown on camera, now JLK is, she's picking things up.
Candyce: [stands up] "It's steaming!" [She claps her hands together. The contents of the pot are finally heating up.]
[JLK goes over to look at computer. Candyce remains at the pot. Malaysia comes back over.]
JLK goes over to stir, Candyce leans in over the pot.
Candyce goes over to computer as JLK stirs.

Malaysia: [walks in between both of them, then **sits at big table]**
Candyce: "It says ... foam at the top." [Reports to JLK at pot]
Candyce goes back over to pot from the computer.

In this episode, notice that everyone seemed to be working autonomously, and even when they were together, there was very little dialogue between them. Notice that Candyce verbally acknowledged the pot was steaming, but the other group members did not respond, partially because they were out of view of the camera. But even when they came back, Candyce did not tell them that it had steamed. The fact that the pot was steaming was important, because they were having problems with the burners on the two stoves in their workspace. It was significant, therefore, to communicate that this time the burners were working. However, Candyce did not communicate this, perhaps because the configurations up to that time had not given her indications of what was valuable to share with others.

Since Malaysia was bouncing back and forth between work surfaces, she missed the initial opportunity to hear that the burner was now working and that the filling was finally cooking. Consequently, she also did not get any signal that it would be useful to check in with Candyce every once in a while to see the custard changing thickness. When Candyce did communicate what she had experienced (e.g., when she saw the foam at the top), she communicated to the facilitator and not to Malaysia, and since Malaysia was at the table, she didn't hear or didn't know to acknowledge this exchange, which would have helped her maintain knowledge about the recipe changes. Overall, the shifting social configurations in Episode 7.11 illustrate the negative effect the three work spaces and the effects of the complexity of the recipe on the ways that the group coordinates the division of labor in the group and the ways that it shifted Malaysia, Candyce, and the facilitator into different places.

However, the group members occasionally were co-located for short periods of time, which helped them to restore communication and awareness of where they were in the recipe preparation process. In Episode 7.12 notice that Malaysia, Candyce, and the facilitator are all grouped around the computer at Work Surface #1. After the facilitator reads the next step aloud, all three of them move over the central table and Candyce pours the fruit tart filling into another container. Notice how they fluidly work together to achieve these activities.

Episode 7.12 (Episode 6.3, Excerpt #3): Working together with Candyce observing - Session 16

JLK: "OK, Malaysia! Moving on, what's the next thing?"
[They all go back over to computer. JLK is at front of computer at Work Surface #1]
JLK: "The next step says..."
[After reading the next recipe instruction, they move over to Work Surface #2.Candyce standing behind Malaysia and JLK but in between them, she reaches in, leans in to get right in front of pot
They pour pot into something else. Candyce pours, Malaysia stirs, JLK stands to side and directs. **They've poured mixture into the pot.**
JLK: [comes over to table and instructs Malaysia] keep stirring.
Malaysia: "I love..."
Malaysia: "It smells good."
Candyce off to side

The verbal interactions in this episode may seem trivial, but when you look over the corpus of transcripts for this group, this episode is an example of how well this group can work together and share their observations when they are co-located. While this pattern only occasionally occurred in Malaysia's small group, it was very common in Case #1 when participants maintained a centralized social configuration throughout the duration of the session and program. This episode suggests that if Malaysia's group had had a centralized work surface, they, too, may have had more communicative interactions.

Even when not co-located, it is possible under some conditions for a group to interact well. Episode 7.13 highlights the effects of agency on the part of a participant in overcoming barriers that orient group members in decentralized social configurations away from activities of other participants. During this episode, Candyce had the responsibility of stirring the tart filling until it thickened. Even while stirring, she kept up with what was going on, moving to the computer once and making sure she knew what was going on at the table, which was behind her. .

Episode 7.13 (Episode 6.3, Excerpt # 4): Division of labor force (switching work surfaces) Stirring the pot (waiting for water to boil) and Cutting fruit
Session 16
JLK walks over to computer, Candyce walks with her.
Candyce is stirring on hot plate.
JLK comes over and is looking in, talking.
Malaysia runs off to get something.
JLK goes off.
Candyce remains at pot. JLK: [to Candyce] "Keep stirring and I' m going to go do something."
[Candyce remains at pot stirring. Other girls [CTNY, AS, CHI] come over and look in pot.]
JLK: [comes back to the table]: "Look what I found." [Bringing over fruit]
Facilitator [asks Malaysia]: "Do you want to cut some fruit?"
[Candyce continues to stir, JLK, Malaysia walks over to the table.
Candyce remains at stove, Malaysia and JLK go to table to get Malaysia cutting the fruit
Candyce stirs and looks over]

This episode illustrated that Candyce was actively trying to stay engaged in the activity by watching what was going on with the pot moving periodically to the computer to figure out what to do next. Throughout Sessions 16 and 17, Candyce engages in this pattern of observation and monitoring (Malaysia does not), making the effort to know everything that was going on.

Even so, it is difficult to sustain communication when a group is mostly in a decentralized configuration. Episode 7.14 demonstrates the degree to which decentralized social configurations negatively impact communication between participants, even when working next to each other. Even though Candyce was making sure to keep herself aware of what was happening, Candyce and Malaysia found little to talk about when they were working around the same table. Even on a shared surface, this group did not interact as much as the boys' group had in Enactment #1.

Episode 7.14 (**Episode 6.3, Excerpt #7) -** (together and note the lack of talking)
Session 16
Candyce hands off stirring to JLK.
Candyce comes over to table with Malaysia, stands around.
Malaysia asks Candyce if she wants to peel some fruit [I think] tells her to get a knife from over there. [Out of camera view]
Candyce comes back with a knife and begins cutting.
JLK stirs, Candyce and Malaysia cut fruit.
TJ and Nina come over and look at what they're doing.
JLK: "Do either of you want to take over stirring?"
Candyce: "I will! I'm not that good at cutting as you can see."
TLC comes over and says something to Candyce.
Candyce takes over the stirring.
JLK goes over to the fruit, tastes some of the fruit.
Malaysia: "Strawberries sweet?"
JLK: "Mmm hmmm."
Candyce: "I think it's done!"
[Candyce continues to stir.]
JLK is at computer.

Though division of labor was flexible (Candyce did some fruit cutting), each of the girls was invested in the success of her part of the activity – Candyce in the filling and Malaysia in the fruit. Even when together and sharing a task (fruit cutting here), there was little to talk about that was interesting to both girls. Candyce soon moved back to stirring the pot and moved away from Malaysia again.

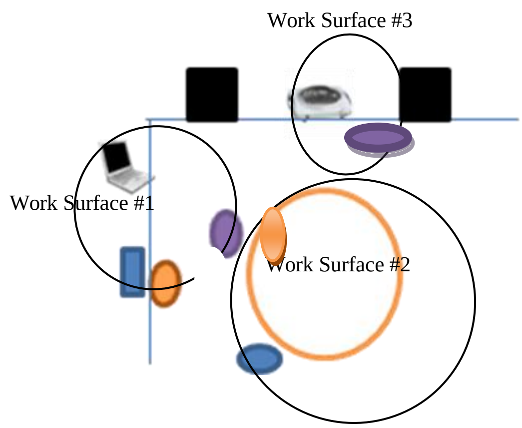


Figure7.9 Episode 7.14 Social Configuration

Episode 7.14 included several levels of interaction. There was activity on three work surfaces, but only one of them was the one where cooking and scientific phenomena were taking place (the burner, Work Surface #3). Because each group member invested herself in a different part of the recipe preparation, each on a different work surface, the kids of interactions seen in Enactment #1, when group members switched off tasks, didn't happen. My hypothesis is that the decentralized configuration, and its distribution of resources across the many surfaces, played a big role in leading the girls to each invest themselves in a different part of the recipe preparation. This, in turn, I think, led to a lack of need to become interested in what the other group members were doing, leading to very different types of interactions than in Enactment #1.

7.3.3.4 Effects of Decentralized Social Configurations on Participants' Attention to Other Participant Notifications leads to Missing Critical Phenomena

Inability to hear what other group members are saying when work surfaces are far apart may also play a role in discouraging sustained interactions between group members. That may have been happening in Episode 7.14, and it is certainly happening in other episodes. In the next few episodes, I will show how the closed and distributed nature of the configurations inhibited the hearing of cues and the observing of critical phenomena, both of which were intended to be experienced in the small-group configurations.

Episode 7.15 illustrates the ways that participant orientation and placement within a decentralized social configurations prevented participants from hearing and observing an important conversation that shaped future conversations about the fruit tart filling. Episode 7.15 comes from Session 17, the second session where Malaysia, Candyce, and the facilitator made the fruit tart. In this episode, Candyce and the facilitator were working at Work Surface #3, the counter with the hot plate. Notice that Malaysia was not included in the interactions revolving around the change in consistency of the tart filling. Malaysia was at the table cutting fruit for the second fruit tart. The foaming was an important change in the fruit tart filling as it was cooking. It was a marker Candyce had noticed the first time they'd made the filling. Recall that this was something Malaysia missed out on because she was at Work Surface #2 cutting fruit.

Episode: 7.15 (Episode 6.10): Session 17 – Case Study #2
(0:05:39.3)
Candyce: “It's supposed to foam at the top right? [Time passes] It's supposed to foam at ...”
JLK responds.
(0:14:13.0) Camera turns to group...
JLK walks around with pot and spoon in hand.
JLK: “Look at it, it's a different texture than last time.”
Candyce looks into pot.
Candyce: “I think…” [Inaudible]
JLK: "... looks thicker. That's good, it's gotta [inaudible] together…” [Does axing motion with hand as if specifying thickness is good so that it will hold together when they cut it?]

In this episode, the decentralized social configuration puts Malaysia at a disadvantage, in that she is positioned and oriented too far away from the phenomena of interest on two separate occasions: the initial verbal cue to a phenomenon of interest during Session 16 and again in this episode.

This episode also highlighted the beginning of an ongoing discussion between Candyce and the facilitator about why the fruit tart filling had a different texture than the one they’d made the previous day. Because of the distributed nature of the social configurations in this group, Malaysia missed the opportunity to participate in the mystery of what had happened to the second custard filling. She had not seen it change consistency the first time, and she did not see what happened this second time. Thus, she didn’t have a point of reference to reason from. If the configuration had been centralized to a single surface, she may have passively engaged in this conversation and taken a peek while she continued cutting the fruit. She could also have more easily been a part of the multiple exchanges Candyce and the facilitator had had about the fruit tart filling.

Missing this opportunity also caused a lack of group awareness of the recipe, which later prevented Malaysia from being able to reflect on the recipe preparation in depth.

In addition to participants decentralized groupings, the physical configurations also seemed to create dead spots in the room. Episode 7.16 starts off with Malaysia, Candyce, and the facilitator positioned within 1-2 feet of each other. Candyce and the facilitator are at the computer (Work Surface #1) discussing the differences in the two fruit tart fillings they created and Malaysia is at the table (Work Surface #2) cutting fruit. Notice that despite being so close that Malaysia didn't seem to be attending to the conversation between Candyce and the facilitator.

Episode 7.16 (Episode 6.11):

JLK: "OK , I don't know so, I mean..." [Talks with Candyce at computer while Malaysia sits behind them at the table cutting fruit.]

JLK: "So, Malaysia."
Malaysia: "Huh?"

JLK: "What could we tell ...that we did last week?"
Malaysia: "That the, um, filling is more ... thinner or thicker..."
Candyce: "Thicker."
JLK: "Oh yeah. [Goes to add that to computer] We don't know why."
Candyce: "But we ... let it stay on there longer, and we might've added more arrowroot."
JLK: "I don't think so."

This episode highlighted that there were dead spots in the social configuration where participants were unable to see what others were doing, or to hear what others were saying because of the physical configuration of the room. This episode also suggested there were several zones that became private or "out of bounds," similar to the dead spots in the physical configuration of the room. For example: Notice that one such dead spot occurred when the facilitator and Candyce were at the computer (Work Space

#1), trying to reflect on the differences between the two fruit tart fillings, while Malaysia, who was sitting at the table (Work Space #2), didn't hear her initially, and then when Malaysia did finally hear her, she didn't stay engaged very long. This episode also highlighted the communication challenges that decentralized social configurations formed: because of multiple work surfaces that were not easily overcome by the facilitator's effort, she was unable to pull Malaysia back into the conversation.

7.3.3.5 Effects of Shifts between Centralized and Decentralized Social Configurations on Experiencing Critical Phenomena (Everyone Present then a Split)

Recall in Chapter 6 that I highlighted a number of opportunities when Malaysia missed seeing critical phenomena firsthand. I suggested then that part of the cause was the parallel nature of the activities, not demanding that Malaysia pay attention to the goings-on in the other part of the recipe. However, the series of episodes I've been presenting here also suggests that the changing social configurations and the non-shared work surface also played roles in inhibiting Malaysia's ability to continuously monitor with ease the parallel recipe preparation process.

In Episode 7.17, all three of the participants were present at Work Surface #2 (the table). Candyce and the facilitator were discussing the texture of the fruit tart custard filling. Notice that Candyce, who had been most vested in monitoring the custard filling as it was thickening, was eager to record her observations in a story or explanatoid.

Episode 7.17 (Episode 6.13): Session 17 – Case Study #2
Candyce (0:21:28.5) reaches for emptied pot and tastes, they discuss what it tastes like
JLK reaches and tastes, she says something about the mouth-feel
Candyce: "That looks [?]."
Malaysia: [reaches in pot, plays around with fingers in pot]

Candyce: “It's good but it's rubbery.”
Candyce: [walks around to computer]
JLK: “Do you want to write - a story or explanatoid?”
Candyce: “Alright, we should say ... [can't hear] …something about one being between the two…” [Inaudible]
(0:23:35.2)
JLK: [inaudible]
Candyce: [It sounds like Candyce is saying she thinks JLK can take notes so she can watch the filling and see something.]
Facilitator, Candyce, Malaysia: [They all walk back over to table.]
Malaysia and JLK: [holds bowl as JLK scoops some more back into pot. They add milk to the pot and put it back on hot plate]
Malaysia and Candyce: [stand over hot plate]
JLK: [walks back to computer]

Candyce took initiative, with her interest fostered by her ongoing interactions preparing the fruit tart filling and seeing all the changes that it had undergone. However, although Malaysia was now present to see and feel these things for herself, she remained silent.

In Episode 7.18, notice how Malaysia, Candyce, and the facilitator are all collectively working on thinning out the filling around a single surface. Notice the ways they were physically engaged and interacting with the filling, observing each other as they did so. Watching and supporting one another in the recipe preparation were very common practices in centralized configurations. However, this episode was remarkably quiet with very little dialogue, suggesting that lack of experience with these types of interactions kept participants from learning from the opportunities these configurations provide. Notice also that Candyce’s verbal observation that it was getting thicker was not met with any type of agreement, or even acknowledgment, from Malaysia or the facilitator, possibly because they spent less time interacting with the filling and seeing its changing texture prior to this episode, and subsequently may not have seen the value of Candyce's verbal observation about the filling getting thicker.

Episode 7.18:
(0:26:50.1)
JLK: [walks over to Malaysia and Candyce at the pot with whisks]
Candyce: [walks over and picks up pie shell, hands to JLK, they pour in the filling] Candyce [picks milk up again as all three crowd around the hot plate]
(0:27:38.7)
Malaysia: [stirs]
JLK: [walks back over to the computer, writes what they did] "Put cream in it."
Candyce: [adds more milk as Malaysia whisks]
Candyce: [goes back and forth between picking things on table up and looking in pot. She picks up milk and pours some in] They all look in
Candyce: "It's getting thick."
Malaysia, Candyce, and JLK: [Malaysia whisking while Candyce and JLK look on]
JLK: [walks off to the computer]
Candyce: [walks away from the area and brings Malaysia something, possibly her cell phone]
Malaysia: [calls JLK over]
Candyce: [looks at computer]
Candyce and Malaysia: [standing at the pot pouring out the fillings that were in the individual pies back into the pot]
JLK: [whisks the entire mixture]

Notice in this episode how Candyce moved back and forth between observing and interacting with the fruit tart filling and the computer recording observation, and then looked at what they should be doing next. Notice how she did not vocalize what she was recording or reading. These two practices were very common in the consistently centralized social configuration earlier. This was further evidence that the distributed/decentralized social configuration prevented groups from engaging in the communal group practices of noticing, sharing, checking, and verbally sharing the next steps.

Episode 7.18 also showed that the group's periodic centralized social configurations restored some of the benefits of centralized social configurations around a single work surface, but did not recover the benefits of continual interactions and experiences in centralized social configurations. Notice that Candyce's experiences primed her for wanting to record observations and to monitor the changing state of the recipe, even without prompting. Thus, periodic centralized social configurations were important for this group to partially recover from the decentralized nature in which the activity was previously and primarily conducted.

Another benefit of centralized social configurations that Malaysia's group was able to take advantage of was recovery from distractions. In Episode 7.19 Malaysia, Candyce, and the facilitator are working on the counter next to the hot plate (Work Surface #3). They pour the filling from the cooking pot into individual-serving sized pie crust. Since it is near the end of the session, Malaysia gets a little distracted by a phone call to her parents for an extension in her pickup time. This momentarily distracts Malaysia from hearing Janet read the story they created. It is not clear from the episode if Malaysia was splitting her attention between the facilitator telling the story and her phone call or just being polite. But when she gets off the phone she appropriately responds to a question about the story asked by the facilitator while she was on the phone.

Episode 7.19 Malaysia on the phone but configuration saves her (How?)

Candyce and Malaysia are at the pot. They're pouring out fillings that were in the individual pies back into the pies.
JLK whisks the entire mixture.

Candyce (0:31:12.1)whisks, Malaysia stands at table on her cell phone, calling someone, JLK at computer
Malaysia leans in to look at pot as she's on the phone. Candyce makes a comment. JLK comes over and looks. She tastes some.
Candyce: “Is it better than before?”
JLK: “I think so.”
Candyce continues to stay at pot.
JLK brings pie shells back over.
L comes over: “What y'all making?” [Holding wooden spoon in her hand]
Candyce doesn't really answer.
JLK: “So here's what I wrote.” [Glances back at Candyce]
JLK reads what she had written.
Malaysia gets off phone and goes back to Candyce.
Malaysia: “Yeah, that's much better.”
JLK comes over too.

Notice in this episode how centralized social configurations like the one Candyce, Malaysia, and the facilitator were in here (around the pot on Work Surface #3) allowed even a partially distracted Malaysia to keep track visually and auditory to what was going on with the filling. Thus, when Malaysia got off the phone, she was able to respond to Candyce’s question about whether it was better than before. This was important because Malaysia had missed earlier opportunities to see the texture change because she was sitting at the table and Candyce was across the space at another work surface. However, because they were at the same work surface, even when distracted Malaysia was able to attend to details and maintain a connection to the activity.

Thus, the spatial distribution of participants and the periods of collective work during the small-group activities fostered a lack of fluidity in group functioning manifested in a lack of engagement in communal practices of attending to verbal cues about important changes in the recipe, and their lack of attending to those cues at later times when they were important. In the next section, I will show how this lack of experiences and interactions limited the scope and depth to which participants could reflect individually and collectively.

7.3.3.6 Reflection

In general, participants in Case Study #2 were in decentralized social configurations, caused by multiple work surfaces that limited the types of experiences participants were able to have in small groups. This later caused participants difficulty in reflecting. In contrast, participants in Case Study #1, who were in the centralized configuration, had diverse experiences, had indirect knowledge of the recipe planning history/process through observing and listening, and were thus able to create a single account of the recipe preparation history/story.

In the next two episodes, I will highlight the difficulties Malaysia had reflecting, in contrast to the fluidity with which Candyce was able to reflect. This disparity between participants' engagement in reflection activities highlights one of the major drawbacks of the distributed social configuration: that the interactions and experiences of participants, working on separate work surfaces within a single work space, with limited or obstructed lines of visual and auditory access, were hidden or not available to other participants, resulting in very individualistic experiences for participants. Thus, I believe that Malaysia's sitting at a different work surface than Candyce placed her at a disadvantage for reflection because she did not have the opportunity to observe the changing texture of the fruit tart filling over time and across batches that Candyce did while preparing the fruit tart filling.

Episode 7.20 highlights Malaysia's difficulty reflecting on the fruit tart filling preparation process after sitting at the central table (Work Surface #2) cutting up fruit while Candyce watched over and stirred the fruit tart filling until it thickened. Notice that how the different work surfaces interfered with directed communication between the group members as they try to create a story that characterizes the fruit tart preparation process.

Episode 7.20: Difficulties in Reflecting for Malaysia
Session 17
16:38
Candyce: [gets up from the table and walks to the sink and turns on water]
JLK: “OK, so we gotta do some writing. OK?”
Candyce: [walks up beside her] “You said laundry? or wri-ting?”
JLK: [clarifies] “Writing.”
Malaysia: “Like in school.”
Candyce: [stands at table]
JLK: [walks to computer to see what it says]
Candyce: [walks over to pot, stirs a little, then walks away]
Malaysia: [is sitting at the table cutting fruit]
Candyce: [reaches over the counter for something]
JLK: “OK, what do we need to do?”
Candyce: [touches fruit or something on the table] “Are the berries washed?”
JLK: “They are.”
Candyce: [picks up things on table, puts them back down]
[JLK and Candyce at the computer; Malaysia at the table cutting fruit]
JLK: “OK, I don't know so, I mean...” [Talks with Candyce at computer]
JLK: “So, Malaysia?”
Malaysia: “Huh?”
JLK: “What conclusions could we draw from what we did last week? Anything?”
Malaysia: “That the, um, filling is more ... thinner or thicker...”
Candyce: “Thicker.”
JLK: “Oh yeah. [Goes to add that to computer] We need to write that somewhere.” [Candyce goes over to the pot, bangs spoon on side] “We don't know why. OK?”
Candyce: “I think it's because we let it stay on there longer, and we might've added more arrowroot.”
JLK: “I don't think so. [Walks over to table] We might've put it on a bit longer.”
Candyce stirs pot.
JLK walks around, grabs spoon, and gets filling out of pie.
(0:18:32.6) Malaysia walks around to Candyce and JLK.

> Malaysia asks about what we're going to do [or something like that]. The next thing I can hear is Candyce clarifying a question: “No, like with the whole entire program.”

The kitchenette in this episode suggests that participants were in a centralized space, but since it was configured with multiple work surfaces, there were many barriers to . Simply walking two to three feet away from where the conversation was happening led both the facilitator and Malaysia to believe they could continue the discussion as if they were all in the same space. However, notice that Candyce’s movement away from the middle table had negative effects on her ability to hear what was going on when she washed her hands and initially mistook what the facilitator said about writing.

Furthermore, notice the way Candyce moved between the pot and the location from which she spoke to the facilitator at the computer, as they reflected on their experiences preparing the fruit tart filling over the previous two sessions. Candyce moved between the center table (Work Surface #2), to the sink (Work Surface #1), to the pot (Work Surface #3), to the computer (Work Surface #1) multiple times within this short two-minute episode.

Also notice that Malaysia’s attention was directed at the table where she was cutting fruit, while the facilitator and Candyce were at the computer. The facilitator tried to include Malaysia in the conversation. Then Malaysia feebly attempted to participate, as she tries to formulate the difference between the two batches but cannot. Malaysia is unable to articulate what the difference is between the two batches of fruit tart filling they created. This is primarily due to the fact that she was not a part of the filling preparation process because she was at a different works surface than Candyce and the pot and she was oriented in a way that would not allow her to monitor the changes in the filling from her position at the table. Additionally, Malaysia was not engaged in the ongoing conversation between Candyce and the facilitator about the differences between the two artifacts. Thus, when not directly engaged in conversation with the facilitator, she drifted back to what she was doing, and wondering about the goals of the KSI project in general.

It seems that a pattern of isolated working had developed earlier in this group's two-day history, considering they were always working individually on one of the surfaces with their backs turned to one another. When the facilitator asked them for observations, only one of them could contribute, and it became a conversation between the facilitator and that single participant; the other participants didn't really have a stake in the conversation because they hadn't experienced it, either directly or indirectly.

In Episode 7.21 Malaysia finally interacts with the fruit tart filling for a prolonged amount of time and which gives Malaysia an opportunity to reflect on what she was seeing at the end of this episode. In this episode, Malaysia, Candyce and the facilitator form a centralized social configuration and Malaysia takes an interest in stirring the pot, while the facilitator and Candyce were actively trying to construct the story.

Episode 7.21 Candyce & Malaysia Reflecting (Centralized Configuration)

Candyce (0:21:28.5) reaches for emptied pot and tastes, they discuss what it tastes like
JLK reaches and tastes, she says something about the mouth-feel
Candyce: "That looks [?]"
Malaysia reaches in pot, plays around with fingers in pot
Candyce: "It's good but it's rubbery."
Candyce walks around to computer.
JLK: "Do you want to write - a story or explanatoid?"
Candyce: "Alright, we should say ..." [can't hear]something about one

being between the two [inaudible- it sounds like Candyce is saying she thinks she can take notes so she can watch the filling and see something]
Candyce, Malaysia, JLK: [They all walk back over to table.]
Malaysia: [holds bowl as JLK scoops some more back into pot]
Candyce, Malaysia, JLK: [They add milk to the pot and put it back on hot plate.]
Malaysia and Candyce: [stand over hot plate]
JLK: [walks back to computer]
Facilitator asks (0:24:51.4)"What's our title?"
Candyce: [looks in and says something inaudible] "Pot."
Candyce: "It's getting thinner." [Watching as Malaysia stirs pot]
(0:25:20.7)
JLK: [brings Malaysia a whisk]
Malaysia: [begins whisking]
Candyce: [peers over her shoulder to see what is going on]
Candyce asks what they called the filling, remembers rubbery
JLK: "OK, so what do you want to say in our story?"
Malaysia turns and says something to Candyce.
JLK: "What do we want to say in our story?"
Candyce walks over to JLK.
JLK: "We followed the recipe for [inaudible]"
Candyce: [sounds like Candyce chimes in] walks back over to Malaysia. She looks in and adds some more milk to the pot.
Malaysia: "It's lumpy."
JLK: "Yeah?" [Sounds like she's typing and saying slowly what she's typing]
(0:26:44.3)

While Malaysia doesn't say much in this episode, she is listening to the conversation between Candyce and the facilitator and shares her observations about the texture of the fruit tart filling.

While Malaysia does have an opportunity to participate in Episode 7.21 on the texture of the fruit tart filling, the extent to which she was able to really reflect on the preparation process is limited. So the facilitator encourages her to talk about what her family and other people thought about the fruit tart.

Episode 7.22 (Extended version of Episode 6.14): Session 16 - Limited scope of reflection: whether people liked it or not. Malaysia talks about her dad

JLK: "Now let's come back and write."
JLK shows Malaysia what she wrote. [Reads it to her]
(0:36:26.3) Candyce comes over, stands behind them, steps up, listens.
(0:37:00.4) Malaysia looks at Candyce and they say something [can't hear].
Candyce reaches back into pot, and then walks over towards middle of room [think she's talking to someone].
JLK: "Do you want to say, do you want to talk about how everybody liked it?"
Malaysia: "But we don't know how they liked it."
Candyce: "Like they could've lied to us."
JLK: "Yeah, except for they told Tammy they liked it..."
Candyce says something [can't hear].
Candyce tells JLK something, Malaysia walks up between them. [I think Candyce is telling her what she told me?]
(0:38:41.2) They're all at computer talking. I think I hear JLK talking about making a new story - they are talking about who told them it was good.
Malaysia: "... it was good, my Daddy ate some... they talked about the texture..."
Candyce stands off some, but looks over at them.
(0:39:26.6) Brittney walks up, talks to Malaysia, plays with Malaysia's clothes.
Brittney: "That's cute!" [Hands on hips]
JLK: [turns around] "Come, so you can see ..." [Malaysia and Candyce come in towards JLK, Brittney walks off.]
0:39:47.9) Candyce looks on, JLK taps her and tells her to look and see what she wrote.
Candyce: "I think its good ..."
...
JLK: "You do too?"
Malaysia: "Yes."

The important part of this episode was that Malaysia, Candyce, and the facilitator were all at the computer speaking, so there was a more dynamic back and forth with the three participants about what to share in the story, compared with when they were distributed.

While Malaysia's small-group experiences didn't prepare her to write in the same ways that the boys' experiences at McDowell School prepared them to contribute interchangeably, the facilitator helped Malaysia contribute to the story by getting her to talk about what her father thought of the fruit tart Thus, when it was time for Malaysia to share in the big-group conversations, she was limited to sharing what was written in the software and what she remembered of the final outcomes of the two fruit tarts. Unlike the McDowell students, she was not able to flexibly share either what she'd written or her experiences because she lacked these experiences.

<u>7.3.3.7 Effects of Decentralized Social Configurations on Reflection: Inability to problem solve/debug unexpected results in recipe</u>

Notice also that since Malaysia lacked the experiences of Candyce, because she was isolated cutting fruit at the table by the distributed social configurations of her small group, her ability to debug why their second filling turned out so differently was limited as well. Notice that despite facilitators' trying to bring her into the conversation, she simply states "I know?" in a questioning yet matter of fact way, suggesting they may never know what caused the second fruit tart filling to be different.

Episode 7.23 (previous - Episode 6.9: – Session 16; exact- Episode 6.12): Session 17 - Limited ability to problem-solve because she doesn't have the experience of the recipe change process to reason with

(0:19:36.1) Malaysia takes pot and pours filling into big pie, Candyce looks on.

JLK: [asks Candyce] "Do you want to taste the whisk?"

Candyce: [tastes the filling off of the whisk]

Candyce: "I wonder what happened..." [Places her hand on her hips]

Malaysia: "I know [?]"

Candyce: "Maybe we added slightly more arrowroot."

JLK says something about knowing they didn't add something.

JLK: “Well, I know we didn't add more than ...”
Candyce looks on as they pour, says something about smoother?
They both look on intently as JLK spreads filling in pie.
Malaysia tastes some filling with her finger.

Notice that Malaysia was only wondering, but it wasn’t very deep, and because she didn’t have knowledge of the entire process, she was not able to participate in a conversation of productive wondering in the same way that Candyce was.

In contrast, notice that Candyce wondered if it might have been arrowroot. Malaysia just tasted the food. Notice that Candyce’s curiosity was piqued from the experience, but this piqued interest did not trickle to Malaysia because she didn’t even have a secondhand experience with the phenomenon; she only overheard the answer relative to the change when asked specifically while constructing the story, and was unable to contribute. It was reasonable to expect that Malaysia might have contributed if the recipe preparation had taken place on a single work surface where she could have witnessed it secondhand.

7.3.4 Section Summary

The episodes in this section illustrate how the physical configuration of the work area made the kinds of centralized social configurations seen in Case Study #1 difficult to sustain. In turn, this meant that many of the beneficial interactions seen in Case Study #1 could not happen naturally and fluidly. As a result, Malaysia missed many opportunities to observe focal cooking and science phenomena and to engage in important conversations about these phenomena. Those missed opportunities prevented her from knowing what had happened, and hence from being able to reflect on the process of preparing the recipe and the changes the recipe had undergone. Thus, she could focus only on outcomes, and she could not participate in conjectures or scientific explanation. This was in complete contrast to Candyce. The results from the McDowell enactment suggest that a centralized social configuration would have fostered more shared activity and understanding.

7.4 Discussion

In this chapter, I've demonstrated two types of configurations using a series of episodes from both enactments. Using episodes from Case #1, Enactment #1, I demonstrated the impact of centralized physical and social configurations on promoting participant engagement. Using episodes from Case #2, Enactment #2, I demonstrated the way a decentralized physical configuration makes beneficial sensory and social interactions difficult, inhibiting participant engagement. With each type of social configuration, I've shown the types of opportunities and experiences the activities provided and then illustrated the ways in which the social configurations shaped the extent to which an individual group member's experiences were shared among the other group members.

When participants work around a single surface in a centralized social configuration, their overlapping horizons of observation (Hutchins, 1995) and the ability to hear other participants allowed each individual to have both and individual understanding and a shared understanding of a recipe's or experiment's preparation history. An open social configuration, formed around a single work surface, afforded the group opportunities to share knowledge, vocalize observations, and vocalize recipe instructions, and seemed to demand that participants report back to their group members their ideas, what they figured out during conversations with the facilitator, and what they observed other groups doing. Each group member was prepared to make and record observations and to share in the big-group discussions. However, multiple work surfaces inhibited this type of engagement and prevented participants from being in the right place at the right time.

The social configurations organized around single work surfaces allowed participants to be oriented in ways where they could see and watch each other while continuing their individual practices/roles/tasks. Thus it provided the greatest quantity of opportunities for participants to engage in the types of experiences the designed activities were originally intended to achieve.

On the other hand, when social configuration shifted because participants were working across multiple surfaces, the resulting social configurations often oriented participants away from one another, causing them to focus on their individual tasks. Configurations with multiple surfaces promoted social configurations that prevented participants from seeing what others were doing while performing their tasks, a major benefit of the single surface workspace because it fostered clear lines of visual and auditory access. These benefits then served to facilitate an assortment of within-group practices that fostered learning.

Based on the data presented in this chapter, one can presume that the extent to which Malaysia continuously monitored other participants and attended to social cues was impeded by the social configurations that were formed in the small-group workspace. This was demonstrated as follows. (1) When the social configurations were such that Malaysia worked over a shared surface, it didn't matter that there were multiple strands of the conversation taking place and that at times she was distracted. Despite these distractions, she easily monitored what others were doing and talking about, sometimes because she occasionally put up her head to look and other times she attended to verbal cues that signaled key phenomena.

(2) In contrast, when she was working in the small group and her group members were spread out over several different work surfaces, they were often separated by physical and auditory distances that made continuous monitoring a difficult activity, rather than a casual activity, as it was for the boys in Case Study #1. This suggests that the structure of the activity played a role in inhibiting cognitive engagement, but it was not the sole influencer. The importance of a common work surface was paramount for participants to engage in the sensory, social, and cognitive engagements that promoted learning. In addition, I've already raised the point that the affordances of artifacts played a role in what participants were able to see, with regard to seeing phenomena and changes in those phenomena.

While this is very intuitive, since no one would make a group work in isolated silos, sometimes the physical configuration of a room forces these types of decentralized social configurations to form within the small group. While it appears that the participants aren't that far apart to impede paying attention to one another, without open line of communication and shared horizons of observation participants do not have much reason to work with one another or to take an interest in what the other person is doing until the end of the activity. Such was the case of the multi-countered kitchen facilities at New Hope, in Enactment #2, but it is easy to overlook participants' orientation to one another in this space, making this a non-obvious but substantial finding that designers and teachers need to consider.

Additionally, decentralized social configurations are particularly problematic in that facilitators and participants have a hard time overcoming the social and cognitive barriers these configurations create. For example, when facilitators visit the environment, they are monitoring the group's progress toward completing the activity, and while the group can be very much on track to complete the activity, not everyone can be engaged in activities or oriented in such a way that give s them access to important science and cooking phenomena. In addition, such configurations are hard to overcome in terms of facilitation.

CHAPTER 8

CONCLUSIONS

My goal in the research presented in this dissertation was to begin bridging the gap between theory and practice in the design and implementation of learning-by-doing learning environments. In particular, I focused on the gap between the goals intended by the learning environment design and how participants take up the affordances of the designed learning goals. This required me to understand participants' interactions and engagement within these learning environments well enough to understand the factors that promote or inhibit their cognitive engagement. I provided two detailed case studies that identified the factors that seem to influence participants' engagement in the intended learning goals of KSI, a learning-by-doing learning environment (Chapters 5 and 6). In addition, I provided a cross-case analysis that identified the affordances of the physical layout and placement of materials in participants' social configurations that promoted or inhibited learning in these case studies (Chapters 7). In this concluding chapter, I revisit the research questions I raised in Chapter 1 and use the two case studies as evidence to answer Research Question #1 (RQ1) and the cross-case analysis to answer Research Question #2 (RQ2).

(RQ1) What are the types of interactions and experiences that promote and /or inhibit learning and engagement in learning-by-doing learning environments?

(RQ2) What are the types of configurations that afford or inhibit these interactions and experiences in learning-by-doing learning environments?

In addition, I reflect on how the findings from the case studies and cross-case analysis inform a preliminary model that highlights the relationship between the moment-by-moment interactions and the social configurations necessary for cognitive engagement and learning in learning-by-doing learning environments. Then, using the model, case studies, and cross-case analysis, I offer suggestions about the selection, structuring, and sequencing of activities, small-group workspaces, and activity facilitation, as well as the design, selection, and placement of materials and technology that **not only afford** engagement and learning of science content and practices, but that **actually result in** such engagement and subsequent learning. Finally, I conclude this chapter and the dissertation by discussing the contributions of this work and future directions for this research.

8.1 Research Questions Revisited

8.1.1 (RQ 1) What are the types of interactions and experiences that promote and /or inhibit learning and engagement in learning-by-doing learning environments?

It is widely believed that collaborative interactions and hands-on experiences promote learning and engagement in learning-by-doing learning environments. In the data and analysis presented in this dissertation, I found that this is indeed true but not always the case.

My data shows that beneficial collaborative and cognitive engagement is promoted by participants' continuous monitoring of artifacts and other participants during learning activities. Continuous monitoring of others and artifacts exposes participants to intended focal phenomena, allows them to see alternatives ways of carrying out activities, and allows them to see the results of others' activities and the differences between others' procedures and artifacts and their own.

Such firsthand and secondhand exposure to activities and artifacts provided KSI participants with experiences in which to ground inquiry and explanation. In Case Study #1, we saw that while not every participant had firsthand experience with every activity and result, those participants who monitored surrounding activity and results had the kinds of secondhand exposure that allowed them to be knowledgeable about the broad range of processes and results across their own group and other close-by groups. When this happened in KSI, cooking activities were not just cooking activities, they were times to create an understanding of why recipes came out the way they did. Participants' continuous monitoring of artifacts and others and their attention to verbal cues allowed them to later reflect on these experiences and draw out rich understandings about how ingredients worked. In addition, in cases where they made a recipe several times, they began to notice when artifacts weren't developing in the ways they remembered them developing from previous experiences and tried to use their understanding to troubleshoot those instances.

Participants' continuous monitoring of others and artifacts and attention to verbal cues also promoted beneficial social engagement patterns: (1) participant positioning and activity coordination; (2) sharing information and collaborative decision making; (3) catching and correcting mistakes and ensuring that the task is done right.

In particular, I found that participants' continuous monitoring of activities and others in conjunction with attention to verbal cues allowed individuals to position themselves in ways that allowed them to remain engaged even as others were taking turns, as seen in the recipe reading done by the group in Case Study #1. Continuous monitoring coupled with actively positioning themselves to have a turn seemed to also mitigate the results of missing out when a participant's attention was drawn away from central learning activities. Engagement characterized by continuous monitoring and positioning for a turn gave participants the opportunity to experience the entire recipe-preparation process and subsequently provided every participant with the experiences they needed to reflect upon and learn from the hands-on activities. In addition, it seemed that the continuous monitoring and attention to verbal cues needed to position themselves served as a natural bridge between participants' goals and the goals of the program.

Participants' continuous monitoring of artifacts and other participants and attention to verbal cues of others led to shared knowledge and shared understanding and, hence, the ability to collaboratively make decisions. Furthermore, the roles that participants took on through their positioning and activity coordination seemed to also affect the information they found important and wanted to attend to or share. When they engaged in beneficial social patterns, they were able to later easily reflect collectively and individually and to effortlessly take turns telling the stories of their learning activities and the rationale behind their decisions.

Such continuous monitoring and attention to verbal cues of others and artifacts also strengthened participants' ability to catch and correct mistakes, ensuring that their activity was done correctly or pushing them to troubleshoot when the process yielded unexpected results. This ability was strengthened by some participants' natural inclinations towards accuracy and by the roles that participants took on through their own and their group's positioning and activity coordination patterns. Participants who engaged in continuous monitoring and were also looked out for new opportunities to participate exhibited an awareness of what activities needed to be done and how they needed to be conducted reflected more readily. Other participants monitoring those individuals who wanted to make sure they got turns took on the same habits of looking ahead and reflecting.

Conversely, Case Study #2 showed that when participants were unable to continuously monitor the progress of activities and attend to verbal cues, they missed important opportunities to see focal phenomena and the changes their artifacts underwent as a result of these phenomena. Participants in this situation were often limited to their own firsthand experiences to reflect back on and had to rely on others to fill in the gaps of their understanding. This left these participants unable to fill in the gaps in their understanding. Without continuous monitoring and attention to verbal cues, participants in small groups will not be able to collaborate in ways beneficial to learning from hands-on activities, as individuals may not have experiences that allow them to begin to explore the disciplinary content intended by a program's design. A lack of understanding or knowledge among some group members may, in turn, further inhibit participants' abilities to take up the affordances of the goals intended by a project or program.

A big issue in making learning-by-doing activities work is helping participants have learning goals (Blumenfeld et al., 1991). Participants' goals for participating in hands-on design and construction activities can often be to only physically engage in the activity and/or to produce an artifact they can take home and share. Differences between participants' goals and program goals can inhibit participants' cognitive engagement, and without the beneficial sensory and social engagement patterns seen in Case Study #1, participants may have trouble findings ways to bridge this gap on their own.

8.1.2 (RQ 2) What are the types of configurations that afford or inhibit these interactions and experiences in learning-by-doing learning environments?

I found that two environmental factors seemed to affect participants' continuous monitoring and attention to verbal cues: the lines of visual and auditory access and the spatial proximity of participants to one another. Overall, I found that these factors seemed to be influenced by the physical layout of the learning environment and the placement of materials.

In particular, I found that mobile and fixed architectural features of the physical layout can greatly influenced the selection and placement of workspaces, which in turn can affect the formation of social arrangements and the resulting closeness of individuals in these configurations. In addition, physical barriers and placement of essential facilities in the learning environment can also affect the degree to which participants are able to have clear lines of visual and auditory access between members of their own group and members of other groups. Such architectural features can affect the extent to which participants' horizons of observation overlap and the degree to which they are able to easily continuously monitor each other and attend to verbal cues.

I found two types of social configurations that seemed to characterize participant arrangements that either promoted or inhibited learning: centralized and decentralized social configurations. Centralized social configurations are those where participants are arranged and positioned in close proximity of one another, fostering open lines of auditory access and promoting continuous monitoring and attention to verbal cues. In contrast, decentralized social configurations, where participants are distributed across multiple surfaces, can impede their lines of visual and auditory access and limit participants' ability to continuously monitor activities of others or artifacts.

Participants' placement within the social configuration and shifts in these configurations during a session seemed to be due in large part to placement of materials (Chapter 7). Thus, placement of materials and room layout collectively seemed to affect the orientation of participants, whether there were clear or impeded lines of visual and auditory access, and the available horizon of observation for continuous monitoring.

In particular, clear lines of visual and auditory access between groups were promoted when materials were placed on centrally located surfaces that were open to all participants. This was seen in both Case Study #1 and Case Study #2 when participants worked at one work surface because the majority of their materials were located on these surfaces. Whereas lines of visual and auditory access were impeded when materials were distributed amongst multiple surfaces causing participants to be oriented away from each other. This was demonstrated in Chapter 7's analysis of the social and material configurations that formed over the three physical workspaces and their affordances for participants' usage of particular materials and ingredients. In addition, when conditions of impeded lines of visual and auditory access persisted, the resulting social configurations affected group dynamics and how participants worked with each other and the information they shared with each other.

8.1.3 Summary of Findings

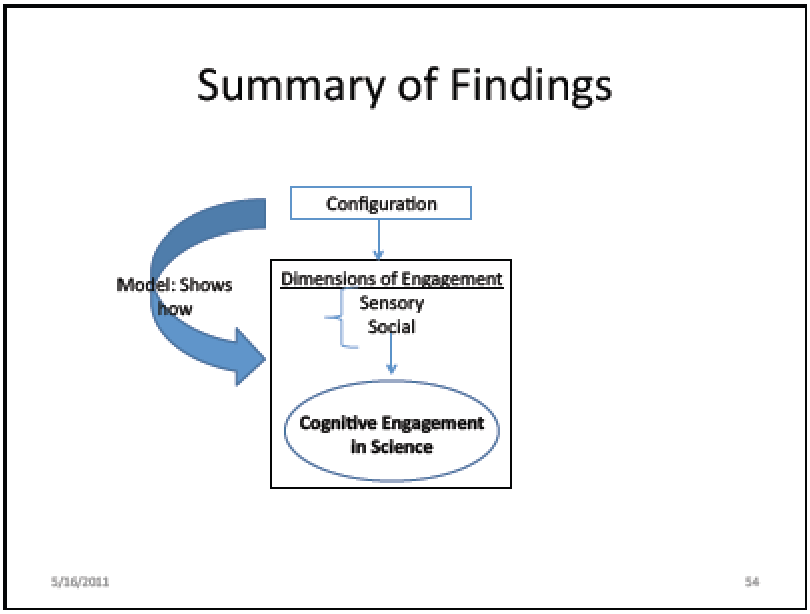


Figure 8.1 Summary of Findings

In summary, I found that the participants' sensory and social engagement, including both their interactions and experiences, affected the extent to which participants cognitively engaged in the activities. When participants were able to continuously monitor other participants and artifacts and attend to verbal cues throughout the entire recipe/experiment preparation activity, they cognitively engaged more deeply during small-group and large group activities. These opportunities created the types of experiences that were important for fostering other physical, social, and sensory engagement patterns of behavior (e.g., participant positioning and activity coordination) that seem to influence learning. Additionally, this learning was supported or inhibited by the types of social configurations participants formed and the lines of visual and auditory access available to the participants. At times, when participants' sensory and social engagements were inhibited by personal reasons or environmental structural factors, their cognitive engagement was limited. For this reason, centralized social configurations are more beneficial than decentralized social configurations for promoting continuous monitoring and learning.

8.2 Model

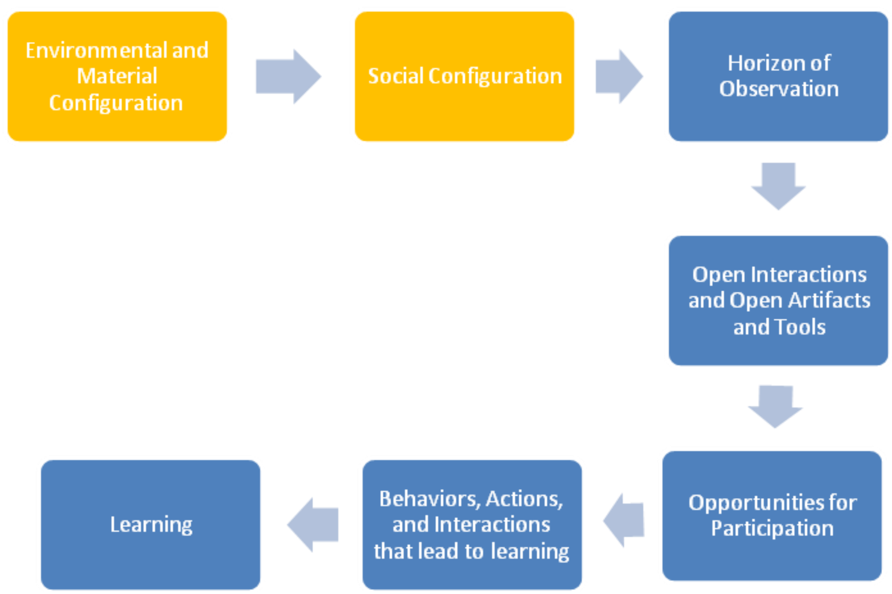


Figure 8.2 Preliminary Model of the Influence of Learning Environment Configuration

In an attempt to pull together the findings of this dissertation and possible implications of the role of the physical layout setup, material configurations, and social configurations on participant engagement and learning, I developed a preliminary model of the influence of learning environment configurations (see Figure 8.2). The model in Figure 8.2 describes the influence that the learning environment configuration has on participants' moment-by-moment sensory and social engagement that promotes cognitive engagement. In particular, it illustrates the relationships between and the influence of the environmental and material configurations on the formation and reconfiguration of social configurations in a learning environment. It further identifies the ways in which these three elements shape the horizon of observation and the types of interactions that are open and available for viewing and hearing which, in turn, shape the opportunities for participation in the environment and the behaviors that participants engage in that lead or don't lead to learning.

This model was developed through the analysis of the interactions and configurations in Case #1, Enactment #1, and was refined through analysis of the data in Case #2, Enactment #2. I will now step through each element in this model by defining each element and describing its relationship to other elements in the model.

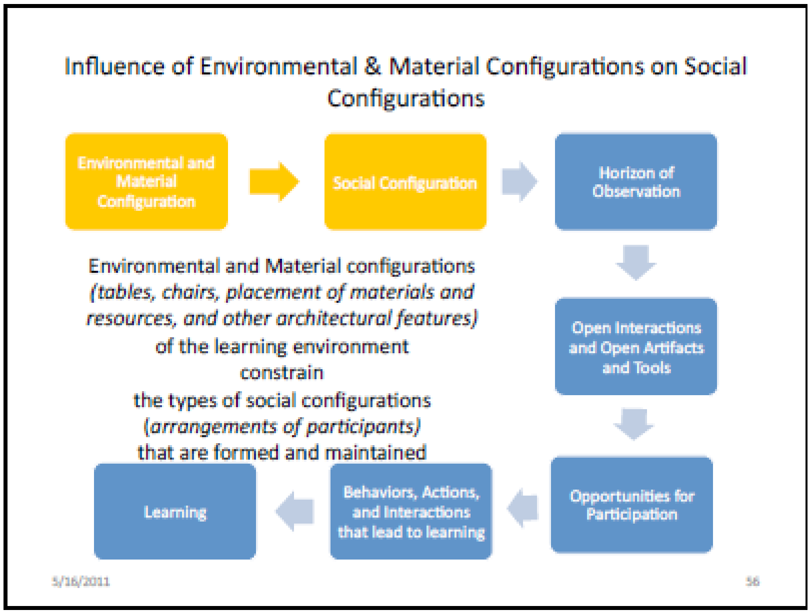


Figure 8.3 Influence of Environmental & Material Configurations on Social Configurations

Figure 8.3 shows the influence of environmental and material configurations on social configurations. The environmental and material configurations (e.g., physical layout of the room, architecture, arrangement of tables and chairs; and placement of materials and resources) of the learning environment shape and constrain the type of social configurations (arrangement of participants) that are formed and maintained. For example, when the architectural features of a room (e.g., L-shaped kitchen counters and center table) create multi-surface workspaces for participants to work, then various materials and resources are spread throughout these work surfaces based on the affordance each surface has for productive work and subsequently so are participants. This results in multiple and changing decentralized social configurations. On the other hand, when the architectural features of a room feature only single table where all of the materials and resources are located, then participants maintain a centralized social configuration with each group member huddled around the single table.

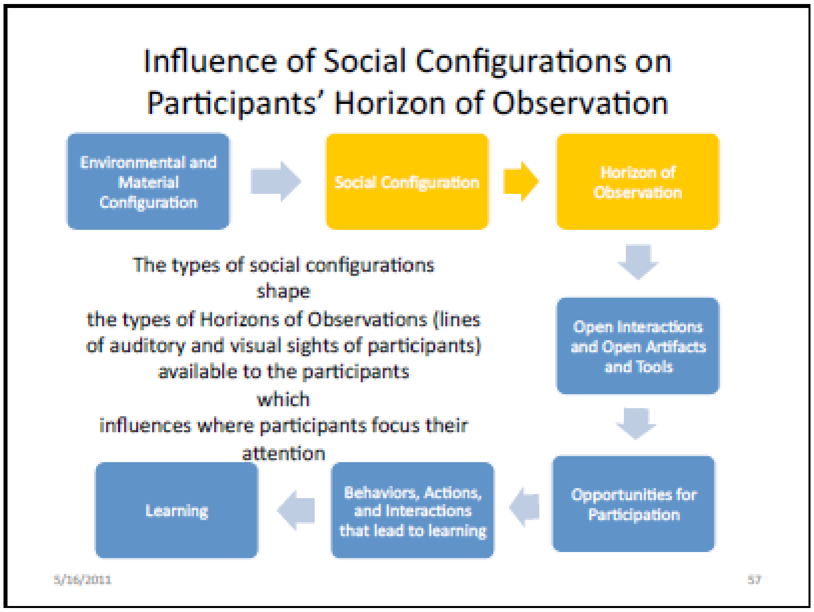


Figure 8.4 Influence of Social Configurations on Participants' Horizon of Observation

Figure 8.4 shows influence of social configurations on participants' horizon of observation. Analysis and findings of the data presented in this thesis suggest that the arrangement of small-group social configuration in the workspace shape the horizons of observation (lines of visual and auditory access) available to the participants, which, in turn, influences where participants focus their attention. For example, when participants are in a centralized social configuration, then the lines of visual and auditory access to what other participants are doing and how artifacts are changing is open for all to see. Thus, participants have shared or overlapping horizons of observation even when engaged in a variety of activities. When participants are in decentralized social configurations, then the lines of visual and auditory access to what other participants are doing and how artifacts are changing are limited to individual's current activity and physical orientation. Thus, participants are more likely to not have shared horizons of observation when engaged in multiple activities.

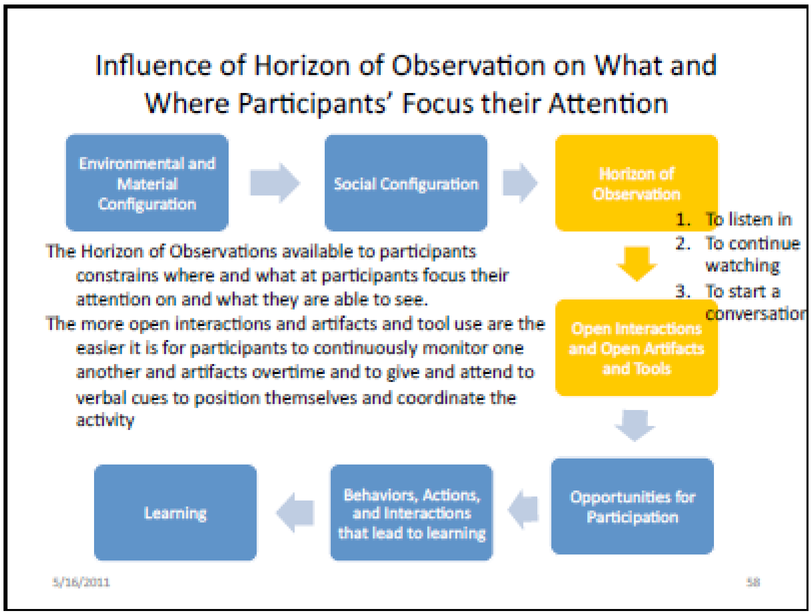


Figure 8.5 Influence of Horizon of Observation on Participants' Attention

Figure 8.5 shows the influence of horizon of observation on what and where participants focus their attention. The horizons of observation available to participants constrains where participants look, what at they are able to see, and what they are able to hear. Thus, some horizons of observation support continuous monitoring and attention to verbal cues, and others make it harder. The degree to which interactions, artifacts, and tools used are visible and open for inspection influences the degree to which participants are able to continuously monitor one another and artifacts over time, as well as to give and attend to verbal cues in order to position themselves and coordinate the activity. For example, when participants can easily see each others' interactions with artifacts and the changes in these artifacts, then they are more likely to engage in continuous monitoring of artifact and others and to attend to other participants verbal cues. When participants cannot easily see or have to change their physical orientation or focus of their activity, then they are less likely to engage in continuous monitoring of artifacts and others and to attend to verbal cues.

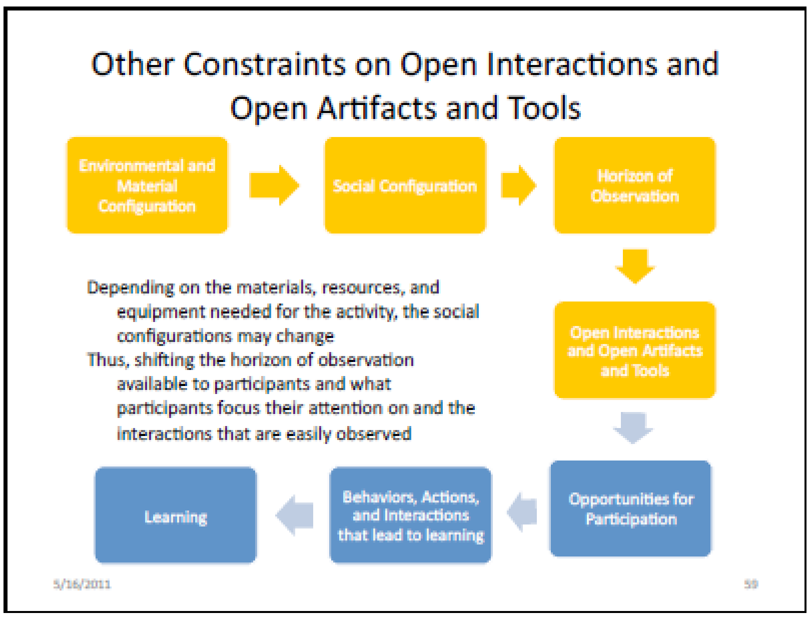


Figure 8.6 Other Constraints on Open Interactions and Open Artifacts and Tools

Figure 8.6 depicts the other constraints on open interactions, artifacts, and tools. It shows that, depending on the materials, resources, and equipment needed for the activity and the placement of these materials in the work space, the social configurations may change. When social configurations change, they often shift the horizon of observation available to participants. This horizon of observation shift affects what participants focus their attention on and the interactions that they easily observe. For example, when materials are distributed across multiple work surfaces, then decentralized social configurations form and participants often move between these surfaces based on the focus of their activity task to be completed. This may result in participants missing important experiences and phenomena because they are not oriented in a way to easily and unintentionally observe activities on other work surfaces. When materials are one a single work surface, then centralized social configurations form and participants are fairly immobile and few horizon of observation shifts occur.

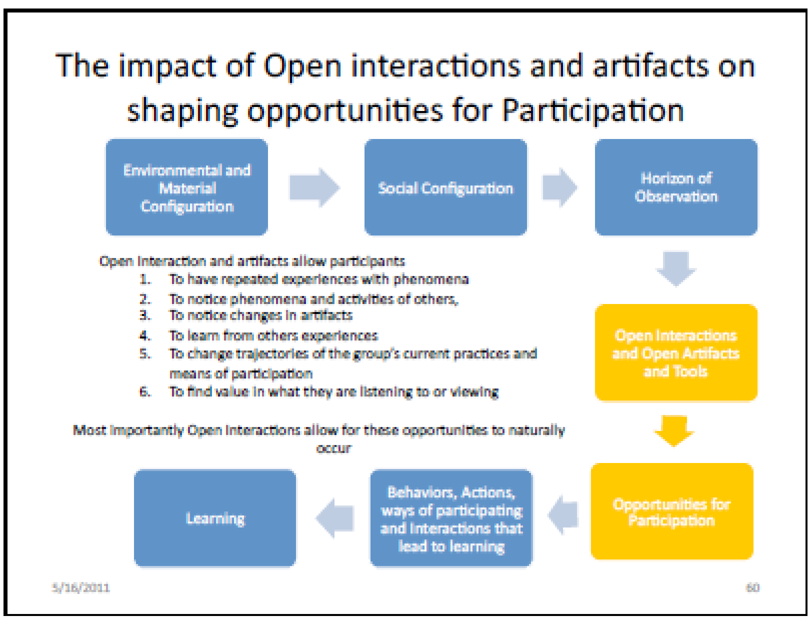


Figure 8.7 The Impact of Open Interactions and Artifacts on Shaping Opportunities for Participation

Figure 8.7 highlights the impact of open interactions and artifacts on shaping opportunities for participant engagement. As discussed earlier, by virtue of participants being in a workspace with a centralized social configuration, participants end up being arranged and oriented in ways that allow them to take full advantage of clear lines of visual and auditory access provided by the horizon of observation. Thus, they are able to observe and listen attentively while carrying out their own activities. By watching these open interactions, participants have opportunities to see artifacts over time and notice changes in these artifacts and ultimately notice important phenomena. This type of unintentional continuous monitoring and its affordances for creating opportunities for participation characterize the first impact that open interactions and artifacts have on shaping opportunities for participation.

The second type of impact open interactions and artifacts have on shaping participation happens once participants notice changes in artifacts or other participants activities which sparks participants' interest and participants begin intentionally continuously monitoring. Such monitoring often leads to discussion about artifacts and comparisons between artifacts. For example, when participants in Case Study #1 noticed that their yeast-air balloon water bottle began filling with foam, it piqued their interest and they began to monitor how it changed over time. Later when one of the participants verbally acknowledge the drastic change in the bottle's contents, the participants began discussing what they observed about the bottle over time.

Thus, open interaction and artifacts allow participants to continuously monitor and attend to verbal cues, which lead participants to experience important cooking and scientific phenomena and have repeated experiences with phenomena. It promotes changes in artifacts and learning from others' experiences. In addition, it provides opportunities for participants to position themselves by allowing participants to change trajectories of the group's current practices and means participation. In addition, it provides opportunities for participants to find value in what they are listening to or viewing and to continuously monitor and attend to verbal cues.

Moreover, open interactions provide opportunities for participants to experience the entire set of learning activities, some through firsthand experience, and some secondhand; to experience focal phenomena and critical changes in artifacts due to the focal science phenomena; to pay attention to discussion, explanations, and demonstrations that highlight the underlying science; to participate in discussions by listening to others' answers, answering questions, and asking questions; and to apply science understanding to refine project artifacts and solutions, debug mistakes, and critique others' applications of lessons learned.

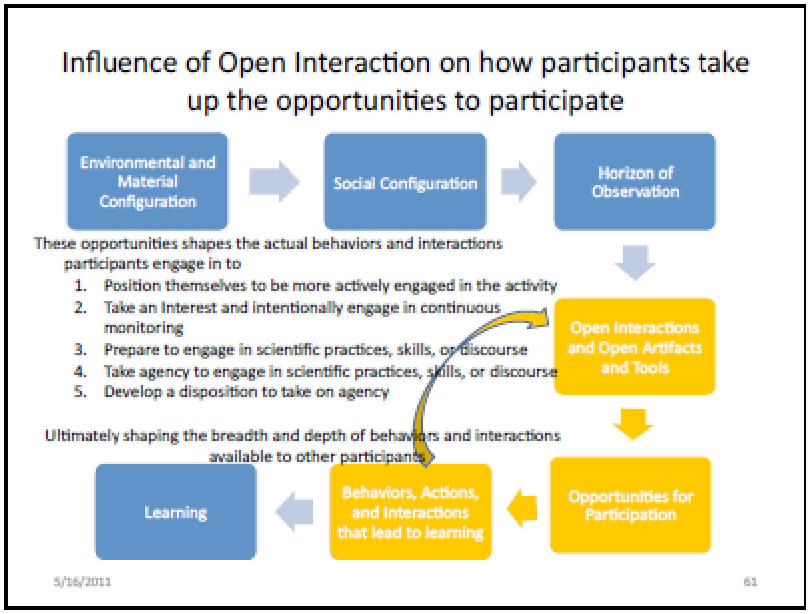


Figure 8.8 Influence of Open Interaction on Opportunities for Participation

Figure 8.8 highlights the influence of open interaction on how participants take up the opportunities to participate. These opportunities shape the actual behaviors and interactions of participants. When participants can watch other participants and track the progress and direction of the activity, participants can position themselves to be more actively engaged in the activity; to take an interest and intentionally engage in continuous monitoring; to prepare to engage in scientific practices, skills, and discourse; and to develop a disposition to take on agency. In KSI, this ultimately shaped the breadth and the depth of behaviors and interactions available to other participants. For example, when participants were able to watch what other participants were doing they were able to shift from less active to more active roles at times when active participants needed assistance finding an ingredient or tool or recall the reasoning behind why the group made certain decisions even when the individual may not have made the decision personally.

Notice the feedback loop between behaviors, actions, and interaction that leads to learning and/or open interactions, open artifacts, and tools. This feedback loop shows that the degree to which interactions and artifacts are open (e.g., visible and accessible) initially encourages participants to participate through positioning and activity coordination, and that such intentional participation then leads to more interactions and artifacts being visible and accessible.

For example, in KSI, participants were able to position themselves when their horizon of observations allowed them to see open interaction of others and artifacts, such that they saw and/or heard that an ingredient was needed. This created an opportunity for participants to become more actively engaged in the activity and to gain an awareness of the recipe-preparation process. This also led to participants engaging in behaviors such as seeking out and acquiring essential ingredients, tools, and equipment, and vying for a turn in the preparation process. These behaviors also led to participants' intentional engaging in continuous monitoring and attending to verbal cues.

With respect to activity coordination, once participants have different materials required to complete a particular step, they can continuously monitor what others are doing and the direction of activities while waiting for their turn. Thus, the activity can become coordinated as each participant has kept hold of some material, and participants then must negotiate individual responsibilities and timing, which puts more interactions into the open.

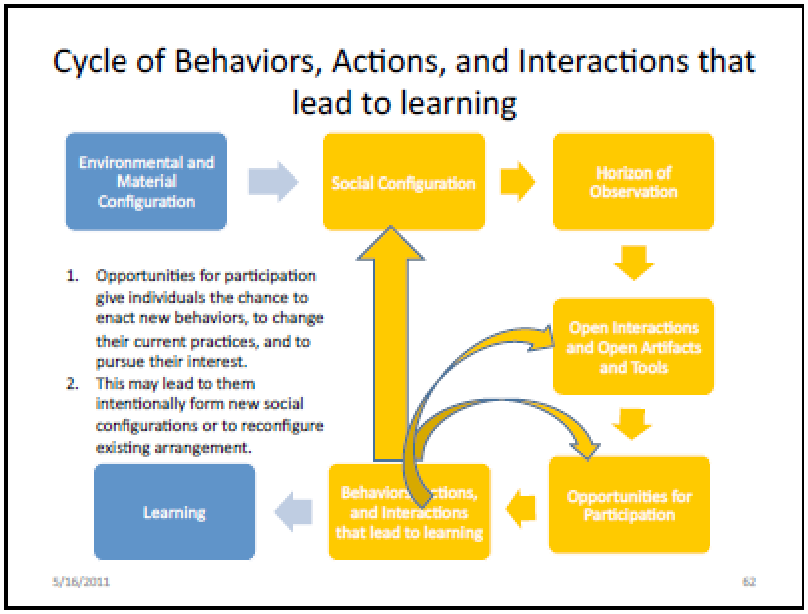


Figure 8.9 Cycle of Behaviors, Actions, and Interactions that lead to Learning

Figure 8.9 identifies the cycle of behaviors, actions, and interactions in learning-by-doing learning environments that lead to learning, along with relevant examples. As noted earlier, the particular behaviors, actions, and interactions that lead to learning include participants asking and answering relevant questions that indicated their science understanding, verbally articulating connections between what they saw and science explanations, responding to the needs of other participants, collectively making decisions and making sure that activities were carried out correctly, debugging mistakes, and interpreting experiences using science understanding.

The initial cycle of behaviors, actions, and interactions in the model is governed by the relationship between social configuration and the horizon of observation they provide for participants to see and hear open interactions, artifacts, and tools. These shape opportunities for participation and lead to participants engaging in behaviors, actions, and interactions that lead to learning. Over time, as participants begin to behave and interact in different ways, they may shift their orientation or position in the social configuration. This shift can have affects on the horizon of observation that are available to participants and what interactions and artifacts are now open or closed.

On a smaller scale, there are two feedback loops that link participants' behavior to open (e.g., visible and accessible) interactions, artifacts, and tools as also noted and discussed in Figure 8.9. In addition, I have noted a direct feedback loop between behaviors, actions, and interactions that lead to learning and opportunities for participation, illustrating the observation that new opportunities for participants to participate opened up once participants chose to behave and interact in certain ways.

An example of this kind of opportunity occurred in Case Study #1 when Craig positioned himself as the leader of the group. His self-positioning provided more opportunities for him to participate in a leadership role. Craig found that if he read recipe instructions to himself he would be able to govern the opportunities available for him to retain ownership of the direction and implementation of activities.

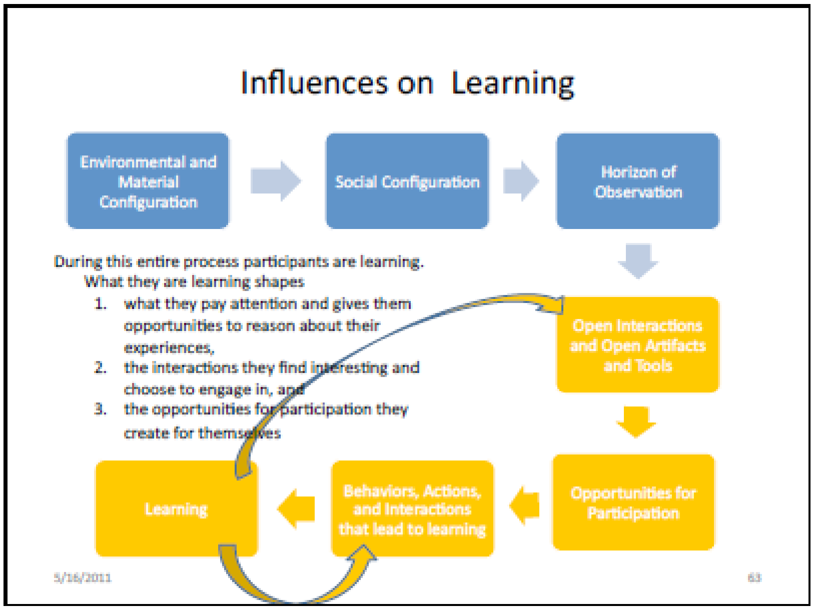


Figure 8.10 Influences on Learning

Figure 8.10 identifies the ways later activities can be affected by earlier ones in learning-by-doing learning environments. These include participants' learning of science content (e.g. the role of acids and bases, the science behind how starches work, and how yeast works), science and practical skills (e.g. measurement, the importance of accuracy and precision, and other cooking related skills), and scientific reasoning skills (e.g. designing experiments, making and recording observation, making predictions, sharing results, drawing out conclusions and lessons learned, applying lessons learned in new situations, and iteratively revising their understanding).

Learning, in this model, is happening continuously, as a result of participating in activities with others. Learning does not happen all at once. Rather, learning is happening dynamically. Participants' learning is shaped by what they pay attention to. What they pay attention to influences the reasoning they can do about their experiences, the interactions they find interesting and choose to engage in, and the opportunities for participation they create for themselves.

The configuration of the learning environment influences what it is easy for learners to pay attention to. When artifacts are visible, when tools are available, when other groups are visible, and so on, participants can pay attention to any of those things. When their group members are carrying out a procedure in a way they can see, they can pay attention to that. What is visible shapes opportunities for participation. These opportunities then lead to participants enacting behaviors, actions, and interactions that promote learning and cognitive engagement both in small-group activities and in big-group activities. Sequencing activities in ways that make relevant phenomena and the experiences of others visible will promote paying attention to those. The feedback loop in the model between learning/cognitive engagement and open artifacts and tools supports the goals of activity sequencing to provide participants with opportunities to see interactions and artifacts in multiple contexts. In addition, there is a feedback loop between learning and behaviors, actions, and interactions that lead to learning. This feedback loop represents the relationship between what participants learn and know and how that shapes how they behave and what they notice and see in interactions that they hadn't seen or notice prior to learning something new or being able to participant in particular ways.

8.3 Design Implications

The model suggests several important design implications for researchers, learning-by-doing facilitators and designers, and science educators. It is a common instructional design practice to take into consideration the roles that activity structure and sequencing, resources, and facilitation play in promoting cognitive engagement, when setting up the learning environment. The research presented in this thesis suggests that there is also a need to take into consideration how the physical layout of the learning environment (e.g., architecture, mobility of tables, location of resources, and placement of materials and technology) arranges and orients participants to support their continuous monitoring, attention to verbal cues, positioning, and activity coordination. .

Supporting this type of participant engagement is important because it allows participants to take up the affordances of the intended cognitive engagement goals of the program. In this subsection, I use the model just presented to make recommendations about the selection and setup of the learning environment's physical space, including placement of essential materials and technology and optimal arrangement of both participants working in small-groups and those gathered for whole group conversations. In addition, I provide recommendations for activity structuring and sequencing and the role of facilitator that promote cognitive engagement and learning.

8.3.1 Design Implications for the Arrangement of the Physical Space of the Learning Environment

My findings and model suggest that selection of the learning environment space should be part of the initial design of a learning environment and strategies for how to promote physical, social, and cognitive engagement and learning in learning-by-doing learning environments. In particular, learning environments that have horizons of observation that provide open lines of visual and auditory access are highly preferred because they maximize participants' continuous monitoring and attention to verbal cues. Learning environments with architecturally fixed facilities (e.g., walls, counters,

counters, stoves, etc.) that create barriers to observing other participants or artifacts or that make hearing other participants difficult should be avoided because they reduce opportunities for participants to continuously monitor other participants and artifacts and attend to verbal cues. Therefore, whenever possible, try to find spaces that are open (free from architectural barriers) and have moveable furniture which ensures a workspace with open horizons of observations (clear lines of visual and auditory access) between participants within a group and across groups.

When considering placement of multiple groups and how much space to provide each group, it is important to provide participants enough space to work comfortably, but not so much space such any individual participant can become isolated. Work surfaces should be configured so that groups to view other groups and also maintain visual and auditory access to the own group's work. The goal is to maximize the affordances of small groups working in close proximity to one another for continuous monitoring and attention to verbal cues.

Arranging multiple small groups in close proximity to one another promotes participants' cognitive engagement in the activities of other groups, and this, too, can be an advantage. I found that when activities of each small group were within a reasonable line of sight, participants communicated effortlessly across groups. This also promoted more opportunities to see important phenomena and for participants to make comparisons between their artifacts and observe practices of other groups.

These findings are consistent with ethnographic descriptions of the Vai and Gola tailors in Lave and Wenger (1991). These descriptions illustrated that when the tailors were oriented towards each other and able to see the entire process of garment preparation and creation such that when they moved into different roles they were able to perform the tasks more proficiently. In addition, Hutchins (1995) talks about quartermasters being able to observe each other as they performed their roles, allowing them to learn aspects of the next level before they were trained to do so.

Recommendations for Selection and Arrangement of Physical Layout

1. Avoid choosing environments with fixed facilities, resources, and architecture features that can limit the lines of visual and auditory access of participants working within a group and across groups. Instead try to use physical spaces with furniture that is movable or can be easily rearranged. Try to arrange the general setup to allow enough space for participants to work but not too much space where participants can be isolated.

Figure 8.11 Recommendations for Selection and Arrangement of Physical Layout

8.3.2 Design Implications for Arrangement of Small-Group Configurations that Promote Cognitive Engagement

In addition to selecting a physical learning environment that allows you to flexibly setup the learning environment in a way that promotes clear lines of visual and auditory access, individual small group workspaces should be configured to promote continuous monitoring and attention to verbal cues. My findings suggest that continuous monitoring and attention to verbal cues fostered cognitive engagement when group members were arranged around a single workspace where all members can see each other carrying out their tasks. Thus, whenever possible, participants should be arranged around a single surface and oriented in such a way that allows participants to view the activities of other participants in their group and observe how artifacts change over time.

This arrangement allows participants to reap the benefits of working in small groups by providing the physical structuring that facilitates the collaborative design and observation of artifacts due to participants being able to see and hear each others' activities and comments. Thus, providing participants with opportunities to cognitively engage because they are trying to make sense of what the other participants are doing and why they are doing it. This physical structuring also provides redundancy in that participants are able to make sure that things are done correctly (similar benefits have been reported in studies of participants engaged in pair-programming).

Additionally, this physical structuring allows participants to track how the artifact develops both as a result of their interactions with it and as a result of the chemical and biological process that allow it to develop on its own over time. Furthermore, it also allows participants a chance to build up a visual and auditory history of the changes artifacts undergo during the small-group activities.

Avoid arranging participants around multiple work surfaces that orient participants away from seeing each other or that otherwise isolate participants from their group. When participants are in such social configurations it limits opportunities for them to continuously monitor and to fully engaged in the design of artifacts and to see important changes in artifacts. For example, my findings show that when participants are separated because they work on multiple work surfaces, they often miss opportunities to hear what other participants are saying which may include important verbal cues to phenomena of interest and changes in phenomena. Then, over time, the participants missed out on seeing the progression of changes that artifacts undergo and the process that promotes those changes. Missing opportunities to continuously monitor often leaves participants at the point where they are unable to debug problems when they arise because they were not there to see the preparation process and places mistakes could have been made.

If multiple work surfaces are necessary, they need to be arranged where participants are oriented toward each other. Thus, remove or eliminate any opportunities for participants to be oriented with their backs to one another. This may require arranging participants and frequently used resources, materials, and technology around a central work surface to encourage usage and to promote prolonged social configurations to minimize the number and length of opportunities where participants may be separated and/or have their backs to one another.

The benefits of centralized work surfaces in promoting continuous monitoring and attention to verbal cues is only fully realized under conditions where participants maintain small-group configurations around a central surface throughout the duration of the activity to enable them to see the changes in the artifacts and the important phenomena they characterize. In addition, my findings suggest that for participants that are not familiar with one another, it may be important for participants to maintain similar groups throughout their participation in the program for the purposes of building continuity of how the small groups function.

Recommendations for Arranging Small-Group Configurations that Promote Cognitive Engagement

1. Arrange a single small-group around a single/central workspace where all members can see and hear each other carrying out their tasks.
2. Remove or eliminate surfaces that may orient participants with their backs to one another to ensure that there is an open horizons of observation for participants within and between groups.
3. Arrange social configurations of small-groups configurations around frequently used resources, materials, and technology on the central work surface to encourage usage.
4. Arrange multiple small groups working in close proximity to one another where the activity of other groups is easily observable and where participants can easily talk to one another.

Figure 8.12 Recommendations for Arranging Small-Group Configuration that Promote Cognitive Engagement

8.3.3 Design Implications for Activity Structuring, Complexity, and Disciplinary Alignment to Promote Cognitive Engagement

Selecting and arranging participants around work surfaces that promote open horizons of observation are only beneficial to cognitive engagement when participants have a reason to value the activities of other group members or peers. Thus, to promote individual as well as collective cognitive engagement of participants in small groups, the structure of activities must be such that all participants are focusing on activities that reveal important scientific phenomena. This requires that activities should be structured in such a way that when major activity divisions are necessary participants have equal opportunities to experience the focal scientific phenomena. Thus, there is repetition of the focal phenomena in each of the activity parts.

In cases, where small division of activities are necessary and focal phenomena cannot be experienced in each of the activity parts, the duration of these activity divisions should be kept as brief as possible and they should be interdependent with the activity that does contain the focal scientific phenomena to motivate participants to maintain monitoring of how the major activity is developing. In addition, no one participant should be stuck doing an activity that does not require cognitive engagement with phenomena of interest, targeted content, or targeted practices.

In addition, for activities that contextualize scientific phenomena, activities should be selected such that it is easy for participants to align contextualized phenomena with abstract scientific concepts. This means that activities must pull out the science that underlies the contextualized activity. In KSI, we achieved this by aligning each cooking activity with a science activity that made the scientific concept apparent.

In addition, it is important for participants to be able to draw out rules of thumb from the activities and easily apply them in new situations. For example, the boys learned that yeast makes things rise. Therefore, they adopted two rules of thumb: (1) add more yeast in order to make foods rise more and (2) decrease the amount of yeast in a recipe in order to decrease the amount that foods rise. Giving participants opportunities to create rules of thumb like these will allow them to use them in new contexts and refine their understanding of how and when to use their newly acquired toolkit.

In addition, activities should be designed with a limited scope of explorations so that participants can apply these different rules of thumb and learn from them. In KSI, we allowed participants to remake the same recipe, but they were only allowed to switch the leavener. By performing a slight variation, it forced participants to be reflective on the science and fostered their awareness of the relationships between ingredients, as well as the similarities and difference between different types of leaveners and the ways to use them.

Recommendations for Activity Structuring to Promote Cognitive Engagement

1. Structure activities that have all participants focusing on aspects of those activities that will allow them to experience the focal scientific phenomena.
2. Reduce places in activities where the activity splits into two independent pieces allowing participants to work autonomously.
3. Eliminate activities where one or more participants get stuck with an activity that does not require them to cognitively engage.
4. 3. Design activities where participants can extract and adopt rules of thumb from their experiences.
5. 4. Sequence these activities such that participants can complete a set of 2-3 of them, allowing participants to develop several rules to interchange and refine their understanding of when and how to use and apply the rules in practice.
6. 5. Choose activities that are similar to previous activities (if not the same), but allow participants to apply and switch rules while refining their understanding.

Figure 8.13 Recommendations for Activity Structure to Promote Cognitive Engagement

Recommendations for Activity Disciplinary Alignment for

Promoting Cognitive Engagement and Learning

1. Design or select an activity that is closest to the domain (e.g., cooking, designing, building, etc.) in order to contextualize and to orient the science

2. Design activities so that they make the science that underlies the contextualized activity salient for the participants (e.g., science experiment that shows the reaction).

Figure 8.14 Recommendations for Activity Disciplinary Alignment for Promoting

8.3.4 Design Implications for Activity Sequencing to Promote Cognitive Engagement

In addition, to promote cognitive engagement of participants in small groups, activities should be sequenced so that participants can iteratively build on their previous knowledge to complete the activities and make decisions about the direction of them. Activities should also be sequenced in such a way that there are repeated opportunities for participants to experience the focal phenomena and refine their understanding of them This is consistent with the suggestions from Bransford and Schwartz (1999) for activity conditions for transfer. For example, in KSI participants were given this opportunity during exploration and retry activities where they remade a recipe of their choosing but changed only one ingredient which was the focal ingredient. This allowed the participant to see the ingredient used in different recipes, modify and refine their understanding of how the ingredient was used, and reflect on the science involved in the recipe. This type of repetition allows participants who miss activities to still have opportunities to experience the focal phenomena. In addition, some sort of repository should be available for participant to revisit their own or other groups' results from previous experiences.

Activities should also be sequenced such that participants can experience unexpected results so that they can use their understanding of the science to reason about what could have potentially caused the mistake. This will promote conversation between group members.

Flexible Activity Sequencing - Participants in informal learning environments have varying degrees of commitment and attendance to such programs however, programs often have activity sequences that provide repeated experiences allow participants that have sporadic attendance and participants at different ZPDs to learn from these programs.

Recommendations for Activity Sequencing to promote cognitive engagement and Learning

1. Sequence activities so that participants can iteratively build on their previous knowledge
2. Sequence activities where there is repetition of concepts and opportunities to experience the focal phenomena
3. Sequence activities so that participants need to make decisions about the direction of scientific explorations of their choosing using their scientific understanding
4. Sequence activities so that participants can have unexpected results and can reason about why their results came out in unexpected ways
5. Provide a repository of activities such that when participants miss an activity and need to revisit the results of other groups they can.

Figure 8.15 Recommendations for Activity Sequencing to Promote Cognitive Engagement and Learning

In KSI, some participants attended weekly, while others were more sporadic in their attendance. Moreover, we had other participants that joined in the middle of the program, entirely missing the initial set of activities. The repeated and graduated opportunities provided by the KSI activity sequence allowed participants who may not have engaged in all the activities opportunities to experience for the first time things that other participants had already experienced and were now building upon. This flexible structure allowed us to meet the needs of both consistently- and sporadically-attending participants.

8.3.5 Design Implications: Role of the Facilitator

To support participants' cognitive engagement during the small group activities, the facilitator plays two critical roles in supporting participants. First, facilitators help participants notice important phenomena, make connections between their experiences, and make connections to the science behind their activities. Second, facilitators model ways that participants can position themselves and coordinate the activities for themselves. Thus, facilitators should avoid directly positioning participants or becoming too heavily involved in the activity coordination as much as possible. Each of these roles is critical to the success and smooth running of the program, and is a successful condition for participant cognitive engagement.

Recommendations for Facilitation to promote Cognitive Engagement

Facilitators should help participants to make connections between their experiences and the related-science by

- Pointing out things they should pay attention to and personally taking interest in activities to spark participants interests
- Helping participants make sense of what they are seeing and to pay attention to important changes in phenomena
- Reminding participants of previous experience verbally or with support of their artifacts
- Revisiting experiment in the context of small-group activities where they are relevant

making the connections for them and over time help them to make the connections themselves

With respect to the first role that facilitators play, facilitators should help articipants make connections between their experiences and the science explanations for their experiences. In particular, this means that facilitators need to point out things participants should pay attention to, personally take interest in activities, and verbally express their interest as a means of sparking participants' interests. In addition, facilitators need to help participants make sense of what they are seeing by highlighting changes in artifacts that denote important cooking and science phenomena and discussing the significance of those observations with participants during the moments of occurrence. This may require helping participants make connections between what they are seeing, explanations of their observations they may have heard before, and their previous experiences. To support these connections, facilitators should draw on available resources such as previously made artifacts, explicitly stated goals, and previously recorded experiments and results.

Figure 8.16 Recommendations for Facilitation to Promote Cognitive Engagement

Thus, I recommend that guidelines and boundaries be decided by designers, researchers, and facilitators to prevent facilitators from losing their objectivity and perspective that is so important for helping participants mature in their levels of understanding from the physical engagement activities. At a minimum, facilitators should engage with participants when participants ask them questions, or if the facilitator notices the group spending too much time managing logistical problems. They should provide the group with resources that they may need, but are not immediately available. All other interactions should be focused on helping participants make connections between activities, notice the underlying scientific phenomena, and experience

When designing and researching a learning environment like this, I suggest a 3:16 facilitator/more capable adult-to-participant ratio, where two people work with the participants and one person manages cameras and the logistics involved with making sure that all materials needed are available and easily accessible. Depending on the research questions and the data needed to be collected, the ratio of facilitators/more capable adults may increase to accommodate videography and ethnography. Thus, the recommendation is no more than two facilitators working with 16 participants directly, because having more facilitators can adversely affect the autonomy of the participants when they work in small groups. Thus, facilitators should move between groups as much as possible and avoid staying with any one group for too long. This allows groups to establish their own means of positioning themselves and coordinating activities so that they assume ownership.

8.3.6 Design Implications for the Materials and Material Configurations

Materials, resources, and tools that are critical to the completion of the activity should be selected to promote seeing the important cooking and science phenomena. In particular, the essential materials that help each group get started in the activity, should be centrally located on a single surface. For example, in KSI, a mixing bowl, spoon, recipe, measuring spoons, and measuring cups were considered essential materials. When essential materials are materials not available, it often causes a bottleneck in the activity. Therefore, these materials should be placed on each group's central workspace to promote collaborative activity coordination, participant positioning, continuous monitoring of artifacts, and naturally-occurring conversations about changes in artifacts that are being or have been worked on during small-group activities. It is not important for all materials to be centrally located in the workspaces, but the majority of materials -- especially essential materials -- should be centrally located on a single surface as opposed to multiple surfaces.

While it is important to have some resources that are dedicated to a group and centrally located on a common surface, having some shared materials may be beneficial to help participants stop or slow down at key places where they can potentially make mistakes. In KSI, we chose to have a shared resource table/cabinet/space where seldom-used resources that were only needed occasionally or for very short amounts of time were located.

The selection of shared materials can also be strategic. For example, in the case of cooking, it might be beneficial to pick an ingredient or tool that allows each group to get to a place in the recipe where mistakes often happen and extra social resources would be beneficial, having seen another group do it before would have been helpful, or when a seeing a product at that point in the development would have been a nice comparison.

Another way the selection of resources can be strategic is when you are trying to manage participants' attention. However, there are always trade-offs. One trade-off is time-off task versus time-on task. Every once in a while a strategic bottleneck may steer participants to important phenomena. However, seeking out materials may cause some participants to be off-task or for a group to be idle for a short period of time (i.e., a couple of minutes) as they await the needed ingredients. This time might be viewed as off-task, but it can also be just the right amount of time to get all the participants on the same page. It might lead to a closer reading of the recipe, checking on what steps have been completed, and reading ahead to see what is coming up next. It may also give the person that is seeking out the ingredient time to look up from what they have been diligently working on to see what it is that they are creating and how other's artifacts look, and to begin making comparisons across artifacts and promoting discussion. Thus, what may seem to be off-task behavior or a bottleneck may, in reality, end up being a few minutes delay in preparation activities that can make the difference between a well-made artifact and the beginning of seeing the significance of that artifact. At first glance this statement doesn't seem intuitive, but the deeper meaning is that you can provide a group with all the resources they need to complete an activity well and they will be successful in that task. However it is harder to get them to put their heads up and think about what they are doing, my recommendation thus, is to use strategic bottlenecks to help physically and cognitively shift and hopefully wonder about their activities and that they mean and why they are doing it in the way that they are or what they are noticing about the underlying science concepts they potentially never really cognitively engage in the activity.

Recommendations for Material Configuration to Provide Cognitive Engagement

1. To promote continuous monitoring of artifacts and naturally-occurring conversations about changes in artifacts that are being worked on or having been worked on, keep these artifacts on participants' work surface so that they can refer to them over time.
2. To support participants making connections across activities and artifacts, (a) keep extra resources available for impromptu experiments, (b) always have artifacts and materials available that allow them to see the science behind the activity and in which they can connect the science explanations to, and (c) whenever possible, ensure that all science explanations or other verbal references to science connections are grounded in physically-present materials or references to materials they have interacted with in the recent past and/or culturally relevant items.

Figure 8.17 Recommendations for Material Configuration to Provide Cognitive Engagement

In order to promote continuous monitoring of artifacts and conversations, slow-developing artifacts should be kept in participants' workspaces so that they can monitor them over time and notice important changes and scientific phenomena. In addition, when possible, artifacts from previous activities should be kept on hand to help participants make connections between activities or to refer back to previous activities. In line with keeping previous activity artifacts on hand, materials for recreating experiments or testing out new ideas should be kept on hand so that participants can make connections between activities and the underlying science phenomena. Furthermore, it is important whenever possible to ensure that all science explanations or other verbal references to science connections are grounded in physically-present materials or references to materials participants have interacted with in the recent past and/or culturally relevant items. Artifacts that are either being worked on or have previously been worked on need to remain in the learning environment for future reference. Extra resources should always be available for impromptu experiments. Important material interactions are interactions where verbal references to the science are grounded in physically-present materials or references to materials one has interacted with in the recent past in the learning environment, or refer to culturally relevant items.

8.3.7 Design Implications for the Technology Configurations

Based on my findings and observations of participants' engagement with technology in KSI, I have found several factors that seem to affect usage of technology: (1) placement of technology, (2) types of technology used, (3) types of technological interactions, and (4) integration of technologies with activities.

Placement of Technology. To promote usage and to reap the benefits of participants' continuous monitoring, technology should be placed in a common location where all groups must meet to use it and in an environment in which they have opportunities to build upon other participants' ideas. However, this might cause the out-of-sight, out-of-mind phenomena. However, if each group's observations or results are broadcast on a big screen, it might drive competition with respect to sharing, recording, and publishing observations. To avoid the out-of-sight, out of mind phenomena, the ideal placement of technology is on a central work surface so that each participant has access to it and can oriented his/herself toward it, making it somewhat unforgettable. This placement allows the technology to play the role of constant reminder for participants to refer back to. Next to the work space, just not good it's often forgotten especially if it is not viewable and not central to the preparation of the recipe or enacting the activity.

Type. Since the workspaces that participants work on often have limited space available, mobile technologies seem to be the best fit for the kitchen. The experiences that KSI facilitators had with laptops suggest that they may not be ideal because they take up a lot of space and are not at a good eye level to be shared by multiple people. With the introduction of a tablet instead, the form factor may work more like paper, which seemed to work really well for the participants. It is easy to pick up paper and shift from person to person, and people standing around a table can see it clearly from different angles.

Some of the unintended consequences for any technology in kitchen environments involve ingredient spillage. Because hands are often messy, the cleanliness and safety of the technology comes in to play. Thus, we need to consider how to keep this device clean and the implications messy fingers cause when using touch screens? These questions have implications on the various responsibilities that participants have, as someone needs to keep their hands clean, but most participants want to still engage in the recipe and experiment preparation process. In addition, typing can be as much of an issue with a tablet as it was with laptops, so there is potential for participants to do speaking messages and take pictures. Separate time needs to then be coordinated and annotated in order to tell a story, or it can be used to present and share with others.

Integration with Activities. KSI facilitators have found that technology is used most when there is a reason for participants to refer back to it throughout the learning process, or else it will be forgotten -- especially in activities where it is not the focus of attention. For KSI, we made the technology maintain all the experiment details including the recipe, and the prompts were placed in ways that fostered frequent references. However, just because a participant refers back to it does not mean that he or she interacts with it long enough to type. For the facilitators, technology was used as a way to organize activity both of the whole group and within the small groups, and for reflection and sharing across groups.

Technological interactions. We found that there are several very important firsthand and secondhand interactions that the participants need to have with the technology. Firsthand interactions included recording observations and data, and visually referring back to it when they had questions. Secondhand interactions included viewing results of others in big group discussions, such as reading what others typed into the software and talking to the person typing.

Recommendations for Technology Configuration to Provide Cognitive Engagement

To promote cognitive engagement with and around technology designed to support activities in learning-by-doing learning environments

Place technology in

- One common location to allow a water cooler effect however avoiding placement that is out of sight of participants oriented around the central work table
- On central work table
- Trade offs
    - Common location, may trigger members of other groups to make observations
        - On Central work table is a constant reminder to refer back to it
        - Integration with Technology with activities as a way to organize activity of the whole group, within the small group, and for reflection and sharing across groups

Types of Technology appropriate for hands-on learning-by-doing learning environments:

- Mobile is a must, desktops too cumbersome
- Laptop (sometimes) – takes up space not a good eye level to be shared by multiple people. It forms a triangle sometimes hard for more people
- tablets (e.g., iPad) -- great potential. Form factor of paper but robust) possibly tablet. Easily adjusted and shared by multiple people and moved around the table.

Figure 8.18 Recommendations for Technology Configurations to Provide Cognitive Engagement

8.4 Contributions

Contribution #1: Confirmation of the Mismatch between Participants' Goals for Participation and Program Expectation for Participation in Learning-by-Doing Learning Environments

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Bridging the Gap between Participants' Goals and Program Goals

Structure activities and learning environments such that they allow participants to freely pursue "having their turn" through allowing participants to oversee all the parts of the activity preparation process increase the opportunities for participants to gain the sensory engagement experiences that the program was designed to facilitate.

While activities and projects were specifically designed in KSI to allow participants to have firsthand experiences with science phenomena, the participants in both enactments were often more concerned with the "doing" involved in the recipe preparation process instead of the observation of important phenomena. My findings suggest that participants were often more motivated to engage physically for the sake of "having their turn."

Wenger suggests that it is often the case that there is a mismatch between the goals of the designer and the user of the designed activities even when it seems like the user is using it in the intended want (1998). Thus, this finding supports the notion of a goal gap in the context of learning-by-doing learning environments.

However, I found that when participants were engaged in continuous monitoring and attending to verbal cues for the sake of having their turn, they also had the opportunity to see the focal phenomena, which promoted deeper physical engagement, piqued interest, and fluid reflection-in-action and reflection-on-action. Moreover, these experiences helped to bridge the gap between participant and programmatic goals.

Constructionist research suggests that people learn particularly well and gain great depth of knowledge when they engage in activities that are personally meaningful to them. However, it is not clear how one can develop a learning environment to meet the interests and cognitive needs of a broad range of participant interests.

The findings from this research suggest that even within a topic, participants' interest can vary. Participants also come with a wide range of goals and reasons for taking an interest in the program. However, bridging participants' interests and goals with those of the activity are more than just aligning topic areas. It is also about ensuring that the process of engagement allows participants to engage in a way that is comfortable for them and gives them ways/options to grow when they are comfortable.

Contribution #2: Description of the Moment-to-Moment Dimensions of Participant Engagement that Fill in the Gap Between Participants' Goals and Program Goals

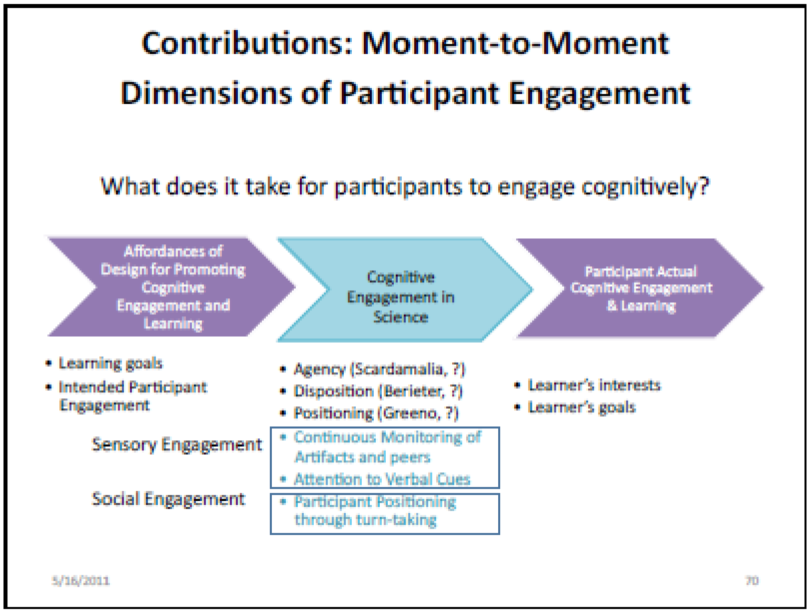

Figure 8.19 Contributions: Moment-to-Moment Dimensions of Participant Engagement

One of the major contributions of this dissertation is that it illustrated that there is a gap between affordances designed into learning-by-doing learning environments and participants' actual engagement. In addition, I highlighted aspects of their participation that allowed them to take up the affordances designed into the learning environment, thus filling in the gap between the intended goals of a program and participants' goals and actual engagement in activities. In particular, I provided a description of the moment-to-moment dimensions of participant engagement that fill in the gap for what it takes for participants to engage cognitively. I found that participants' sensory engagement of continuous monitoring of artifacts and peers and their attention to verbal cues were important for them to take up the affordances of the designed activities' goals and intended engagement. Thus, both the sensory and social engagement were important for participants to take on the intended cognitive engagement goals.

Contribution #3: Identified the influence of social configurations on participants' engagement in a learning-by-doing learning environment

Contribution #4: Identified a relationship between sensory and social engagement that promote or inhibit cognitive engagement in a learning-by-doing learning environment

Contribution #5: Provided a detailed preliminary model that describes how the configurations of the relationship between dimensions of participants' engagement (sensory, social, and cognitive) and social configurations that afforded that engagement

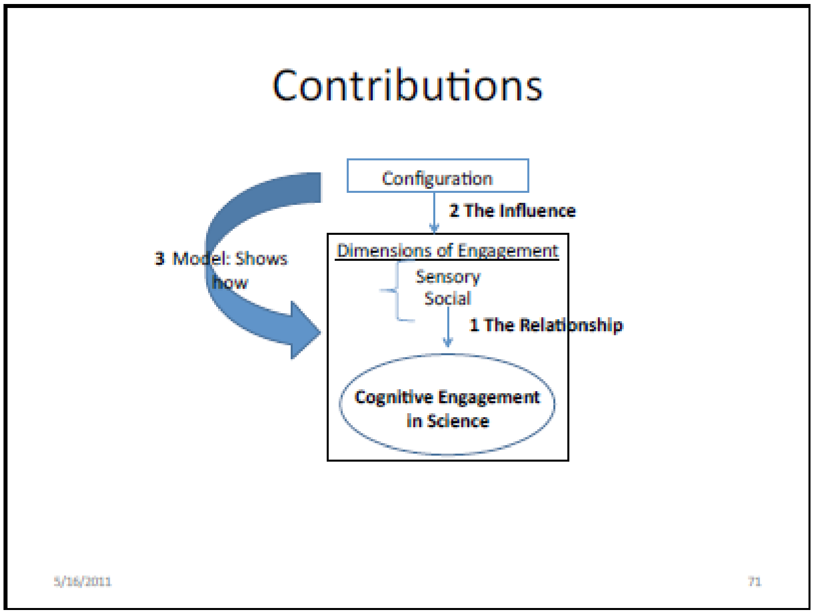

Figure 8.20 Contributions Dimensions of Engagement

I have identified a relationship between the dimensions of engagement (e.g., sensory and social engagement) and participants' cognitive engagement in science. I also saw that there was an influence between the physical, sensory, and social configurations on participants' dimensions of engagement and cognitive engagement. In addition, I provided a detailed preliminary model that describes how the configurations of the relationship between dimensions of participants' engagement (sensory, social, and cognitive) and social configurations that afforded that engagement.

Contribution #6: Design Implications for promoting cognitive engagement in a learning-by-doing learning environment based on the patterns of participant engagement and social configurations for educators and designers

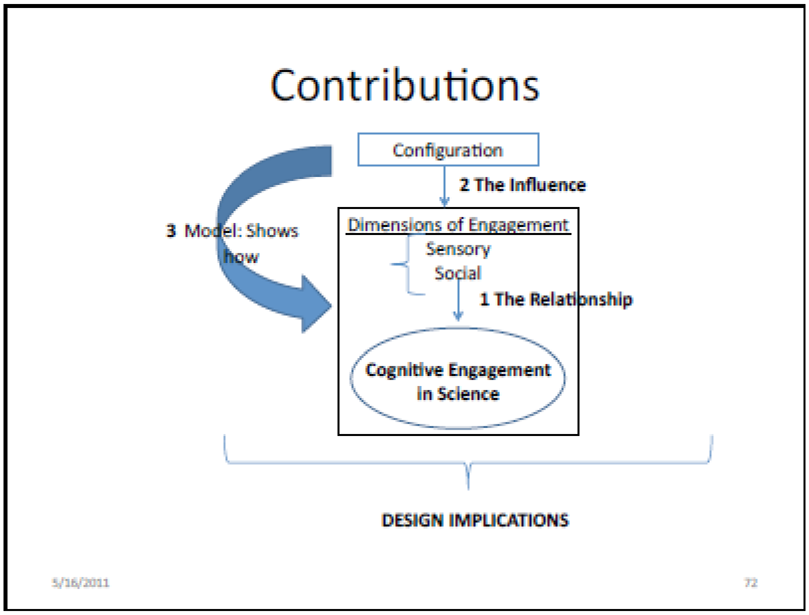

Figure 8.21 Contributions & Design Implications

Lastly, I identified a number of design recommendations to promote cognitive engagement in learning-by-doing learning environments. In particular, I focused on the areas of selection and design of physical layouts of learning environments, different types of small-group configurations, activity design-structuring-sequencing, materials selection and placement, and facilitation.

8.5 Conclusion

Designed educational activities do not always translate smoothly from plans to the actual implementation. A variety of factors, including time, participants' interests, preparation/background, and mood, affect what actually happens in a learning environment from day to day. The facilitator is also an instrumental variant. His/her background, teaching philosophy, interests, and style are only some of the impactful factors that can modify how learning activities are instantiated and managed. In addition, program goals often compete with participants' goals; as a consequence, it is not always possible to anticipate all the different ways of managing a set of activities while planning.

However, I found across the case studies presented in this dissertation that when it is easy for participants to continuously monitor activities of others, they take up the affordances of the intended learning and engagement goals and have the types of firsthand and secondhand sensory experiences that promote the kinds of social and cognitive engagement that promote learning. The model I extracted from my data suggests that the physical layout of the learning environment and the social configurations that form within those layouts are important influences on the ability to continuously monitor and hence the way that participants engage cognitively and collaboratively.

The model, of course, is derived from only a small number of cases. It thus needs to be validated and refined with data from other studies. Nonetheless, the differences in participation when participants could participate closely with each other and when they were more separated was striking and worth considering when designing environments for learning by doing. If the environment cannot be set up for easy monitoring and sharing, activity sequences can be put in place to promote the kinds of monitoring and sharing that promote beneficial cognitive and collaborative engagement .

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